Technical Report

Upper Yuba River Watershed Chinook Salmon and Steelhead Habitat Assessment

Prepared for

California Department of Water Resources

June 2006

Prepared by

Upper Yuba River Studies Program Study Team

Contents

Appendixes

Table

Figures

Acronyms and Abbreviations

°C	degrees Celsius
Authority	California Bay Delta Authority
cfs	cubic feet per second
DWR	Department of Water Resources
ERP	Ecosystem Restoration Program
met data	meteorological data
UYRSP	Upper Yuba River Studies Program
Work Group	Upper Yuba River Studies Program stakeholder work group

Executive Summary

The Upper Yuba River Studies Program seeks to determine whether the introduction of wild Chinook salmon and steelhead to the upper Yuba River watershed is biologically, environmentally, and socio-economically feasible over the long term. In recognition that numerous factors will contribute to an ultimate determination of overall feasibility, the Upper Yuba Studies Program established and initiated a comprehensive study plan to evaluate the various aspects of feasibility, including factors related to habitat, water supply and hydropower, flood risk, water quality, sediment transport, and socio-economics. Studies associated with each of these issue areas were initiated simultaneously and conducted in parallel under the assumption that the upper Yuba River watershed contained habitat capable of supporting those fish species.

In 2003, results of field studies conducted in the upper Yuba River watershed as part of the study plan suggested that water temperatures could be sufficiently high to prevent or limit the use of the Middle and South Yuba rivers by Chinook salmon and steelhead, thereby potentially making introduction of those species infeasible. Based on this observation, continuation of other aspects of feasibility such as fish passage and socio-economic factors was postponed until additional focused analyses of water temperature and fish habitat could be conducted to determine whether there was sufficient habitat to warrant moving forward with the next steps in the overall evaluation.

The focused evaluation of habitat and temperature relied on habitat information collected as part of field studies in the Middle and South Yuba rivers, and generally available information on salmon and steelhead water temperature requirements and life history combined with the results of water temperature monitoring and modeling of the Middle and South Yuba rivers. The analysis narrowly focused on the capability of the habitat in the upper portion of these rivers to support fish under current operations, and assumed for the purpose of the analysis that fish would have unimpeded access to these areas. In addition to the evaluation of habitat and thermal conditions under current operations, the influence of increased flow on water temperatures was evaluated to provide an indication of how responsive habitat conditions might be to changes in flow. The capability of the habitat to support populations of salmon or steelhead was assessed by identifying the amount of potentially suitable habitat and developing rough predictions of the number of fish those areas could possibly support. To provide context, the predictions were compared to other streams that currently support self-sustaining populations of Chinook salmon and steelhead.

To define the extent of thermally suitable habitat, water temperatures recorded during the water temperature monitoring program were compared to the water temperature tolerances of the various life stages of Chinook salmon and steelhead. To better define the downstream extent of thermally suitable habitat, a water temperature model was developed for the upper Yuba River watershed and used to predict water temperatures at intermediate points between the widely spaced monitoring locations. The results for each life stage were integrated to identify the extent of each river that had the capability to support each species by providing both physical habitat and water temperatures suitable for completion of the species' life cycle.

The results of the analysis, based on temperature and hydrologic conditions in 2004, suggest that thermally suitable (below the upper limit of the suboptimal range [19°C]) habitat for spring-run Chinook salmon on the Middle Yuba River would extend approximately 5.6 miles downstream of the natural barrier under current operations. Approximately 0.5 miles of habitat would be within the optimal range (≤ 16°C). If, as observed in Butte Creek, spring-run Chinook salmon in the upper Yuba River watershed were able to hold at higher water temperatures, the range of thermally suitable habitat would be extended downstream. For example, in 2004 approximately 8.8 miles was below 20°C. Based on July and August air temperatures reported at Blue Canyon, 2004 ranked 19th and 17th, respectively out of a 52-year period of record.

On the Middle Yuba River, thermally suitable habitat for steelhead would extend approximately 8.8 miles downstream of the natural barrier to below Wolf Creek under current operations. On the South Yuba River, the analysis suggests that no suitable habitat would be available for either spring-run Chinook salmon or steelhead under current operations because of high water temperatures during the summer period. However, further study and resolution of the temperature of water released into the South Yuba River from Lake Spaulding could influence these preliminary conclusions. Potential spawning gravel would be available throughout the lower reaches of the Middle and South Yuba rivers, and the analysis suggests that water temperatures would be suitable for fall-run Chinook salmon spawning during their anticipated spawning period.

Based on the analysis of available spawning habitat within the identified reaches, it was predicted that approximately 100 spring-run Chinook salmon could spawn within the 0.5 miles of habitat with water temperatures in the optimal temperature range (≤ 16°C) in the Middle Yuba River. It was predicted that approximately 500 spring-run Chinook salmon could spawn within the 5.6 miles of habitat within the thermally suitable range (≤ 19°C) in the Middle Yuba River. For steelhead, it was predicted approximately 650 adults could spawn within the 8.8 miles considered thermally suitable in the Middle Yuba River. Conservative assumptions regarding the potential productivity of these reaches were used in formulating these predictions.

To evaluate sensitivity of water temperatures to flow, the water temperature model was used to predict water temperatures over a range of flows. An upper limit of 50 cfs was selected based on the reasonable limits of the water temperature model. Without changing the water temperature at the release point, increasing the flow releases (up to 50 cubic feet per second) from Milton Reservoir and Lake Spaulding into the Middle Yuba and South Yuba rivers, respectively, would alter the thermal regime and extend the range of thermally suitable habitat for each species.

For spring-run Chinook salmon, the results suggest that thermally suitable habitat in the Middle Yuba River would extend approximately 11.7 miles downstream of the upstream-most natural barrier with increased flow. It was predicted that approximately 1,650 spring-run Chinook salmon could spawn within this reach under conditions of increased flows (50 cfs). For steelhead, thermally suitable habitat in the Middle Yuba River would extend approximately 14 miles downstream of the upstream-most barrier to a location between Wolf and Kanaka creeks with increased flow. Approximately 2,640 adult steelhead could spawn within this reach. On the South Yuba River, results of the water temperature modeling suggest that less than 1 mile of thermally suitable habitat would be available to spring-run Chinook salmon and steelhead with increased flow. However, further study of the temperature of water released into the South Yuba River from Lake Spaulding and refinement of the temperature model could influence these preliminary conclusions. The potential to provide increased flow releases (50 cfs) was not evaluated in the report. Current flow conditions provide suitable water temperatures for fall-run Chinook salmon throughout the upper Yuba River watershed. Therefore, increased flow would not likely provide additional benefit to fall-run Chinook salmon relative to current operations.

The amount of available spawning habitat within thermally suitable reaches served as the basis for predicting the potential number of fish that could be supported by the available habitat. Analysis of available habitat for other life stages of spring-run Chinook salmon and steelhead within the thermally suitable reaches indicated that habitat and thermal conditions within the reaches also could support use of these reaches by the other life stages. Based on this analysis, the results suggest that the thermally suitable habitat in the upper Yuba River watershed under current water operations could support numbers of fish within the range seen in other Central Valley streams that support spring-run Chinook salmon populations, and that increased flow would lengthen the amount of thermally suitable habitat available to both species.

The results of this report indicate that the analyzed habitat and temperature conditions in the upper Yuba River watershed are capable of supporting anadromous salmonids. While these results represent the initial steps in determining overall feasibility of introducing anadromous salmonids into the upper Yuba River watershed, they do not constitute a conclusion that introduction of Chinook salmon or steelhead would be feasible over the long term. Completion of the studies identified in the UYRSP study plan, including additional evaluation of biological and habitat issues, water supply and hydropower impacts, flood risk, water quality, sediment transport, and socio-economics would be required to ultimately answer the remaining questions regarding the feasibility of introducing these fish to the upper Yuba River watershed.

CHAPTER 1

Introduction

1.1 Background

The California Bay Delta Authority (Authority), formerly known as the CALFED Ecosystem Restoration Program (ERP), is mandated to maintain, improve, and increase aquatic and terrestrial habitats and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species. Specific goals of the Authority include recovering at-risk native species in the Bay-Delta and the watershed above the estuary; rehabilitating natural processes related to hydrology, stream channels, sediment, floodplains, and ecosystem water quality; and improving and maintaining water and sediment quality to better support ecosystem health and allow species to flourish.

The Upper Yuba River Studies Program (UYRSP) began in 1998 and evolved as a collaborative effort between local stakeholders and the Authority "to determine if the introduction of wild Chinook salmon and steelhead to the upper Yuba River watershed is biologically, environmentally, and socioeconomically feasible over the long term." Providing Chinook salmon and steelhead access to potential habitat in the reaches of the upper Yuba River that are currently blocked by Englebright Dam would potentially contribute to achieving the Authority's environmental goals.

The 55-member stakeholder work group (Work Group) represents local water, business, and environmental interests, and includes the state and federal resource agencies that comprise CALFED. The Work Group identified six study areas as critical to answering the feasibility question: (1) upstream and downstream habitat; (2) sediment; (3) water quality; (4) water supply and hydropower; (5) socioeconomics; and (6) flood management. The Department of Water Resources (DWR), with the support of the Work Group, contracted a study team composed of technical consultants led by CH2M HILL to investigate each of the technical study areas.

The desired outcome of the UYRSP is a recommendation by the Work Group to the Authority regarding the feasibility of introducing wild Chinook salmon and steelhead into the upper Yuba River watershed.

1.1.1 Scope and Background of the Habitat Analysis

During 2003, existing conditions in the watershed were characterized for each of the technical study areas, including fish habitat. The results of this initial characterization were presented in an interim report (DWR, 2003) that was reviewed by the Work Group and members of a Technical Review Panel convened by CALFED, which was composed of scientists and experts in the technical disciplines covered under the UYRSP. The results of field studies conducted in the upper Yuba River watershed as part of the study plan suggested that water temperatures could be sufficiently high to prevent or limit the use of the Middle and South Yuba rivers by Chinook salmon and steelhead, thereby potentially making introduction of those species infeasible.

Based on this observation, and with guidance from the Technical Review Panel, continuation of other aspects of feasibility, such as fish passage and socio-economic factors, was postponed until additional focused analyses of water temperature and fish habitat could be conducted to determine whether there was sufficient habitat to warrant moving forward with the next steps in the overall evaluation. The focused evaluation of habitat and temperature relied on habitat information collected as part of field studies in the Middle and South Yuba rivers, generally available information on salmon and steelhead water temperature requirements and life history, and the results of water temperature monitoring and modeling of the Middle and South Yuba rivers. The analysis was narrowly focused on the capability of the habitat in the upper portion of these rivers to support Chinook salmon and steelhead under current operations, and assumed for the purpose of the analysis that fish would have unimpeded access to those areas. The uppermost natural barriers on the Middle and South Yuba rivers were used to define the upstream boundary of fish access.

The capability of the habitat to support populations of salmon or steelhead was assessed by identifying the amount of potentially suitable habitat and developing rough predictions of the number of fish those areas could possibly support. To provide context, the predictions were compared to other streams that currently support self-sustaining populations of Chinook salmon and steelhead.

To aid in the analysis, a planning-level water temperature model was developed for the Middle and South Yuba rivers and calibrated using data from 2004. A description of the water temperature model is presented in Appendix A. The model allowed an assessment of the relationship between water flow and water temperature to determine whether increased flows from the upper reservoirs would have a significant effect on water temperatures and the availability and suitability of habitat for Chinook salmon and steelhead.

1.1.2 Document Purpose

This document presents the results of data collection, field studies, and modeling conducted by the study team to characterize current habitat conditions in the upper Yuba River watershed and assesses whether the available habitat upstream of Englebright Dam is capable of supporting Chinook salmon and steelhead. The objectives of this document are to:

- Convey the results of additional habitat analyses in the watershed (based on review of the literature and study results) to the Work Group
- Provide technical background on the methods, analyses, and results of the studies that were conducted on habitat elements for Chinook salmon and steelhead
- Convey results on the extent of thermally suitable habitat (i.e., reaches of the river that contain suitable water temperatures) available for Chinook salmon and steelhead in the upper Yuba River watershed under current water operations
- Integrate the results of the habitat technical studies to assess the capability of the habitat to support salmon or steelhead and develop rough predictions of the number of fish those areas could possibly support.
- Evaluate the influence of increased flows on the amount of thermally suitable habitat for Chinook salmon and steelhead in the upper Yuba River watershed

- Provide the technical basis from which the Work Group could determine whether moving forward with the next steps in the evaluation is justified

This report presents the most current information available on existing conditions in the upper Yuba River watershed. Determining the extent and quality of habitat potentially available to Chinook salmon and steelhead required synthesis and interpretation of field data, information from the scientific literature and modeling results. The determination of whether the available habitat is capable of supporting Chinook salmon and steelhead under existing watershed conditions reflects the consensus of the habitat study team.

1.2 Watershed and Study Area

The Yuba River drains a watershed of approximately 1,340 square miles from the crest of the Sierra Nevada to the confluence of the Feather River near Marysville and Yuba City in the northern Central Valley of California. The Yuba River watershed extends from an elevation of 9,100 feet in the high Sierra to around 30 feet at its confluence with the Feather River. The principal tributaries are the North Yuba River with a drainage area of approximately 490 square miles; the Middle Yuba River, with a drainage area of about 210 square miles; and the South Yuba River, with a drainage area of about 350 square miles. The North Yuba River is the major tributary, contributing nearly 50 percent of the total natural flow originating above the foothills. The North Yuba and the Middle Yuba rivers join below New Bullards Bar Reservoir to form the Yuba River. Farther downstream, the South Yuba River flows into Englebright Lake.

Englebright Dam, a concrete arch structure 260 feet high and 1,142 feet in length, was completed in 1941 to capture gold-rush era hydraulic mining debris (sediment) that represented a flood threat to downstream residents. The dam marks the division between the upper and lower Yuba River. In the upper Yuba River watershed, Jackson Meadows Dam and Milton Dam are the major water storage and diversion facilities in the headwaters of the Middle Yuba River. Our House Dam, located about 12 miles upstream of the confluence of the North and Middle Yuba rivers, allows diversion of water from the Middle Yuba River to Oregon Creek through the Lohman Ridge Tunnel. Spaulding Dam on the South Yuba River impounds Lake Spaulding which receives water from the upper South Yuba River, Fordyce Creek and Bowman Lake through the Bowman-Spaulding Canal. Flow conditions in the upper Yuba River watershed are largely controlled as a result of these and other facilities and existing conditions as analyzed in this report are, in part, the result of augmented flows released from the upper reservoirs.

The primary study area includes Englebright Lake, the South Yuba River below Lake Spaulding, the Middle Yuba River below Milton Reservoir, and the North Yuba River below New Bullards Bar Reservoir. The North Yuba River above New Bullards Bar is not included in the study area due to the presence of New Bullards Bar Dam a few miles above its confluence with the Middle Yuba. This structure is not equipped with fish passage facilities and is a complete barrier to fish passage; providing passage was considered beyond the scope of the feasibility analysis. The upper Yuba River watershed, including the study area is depicted in Figure 1-1.

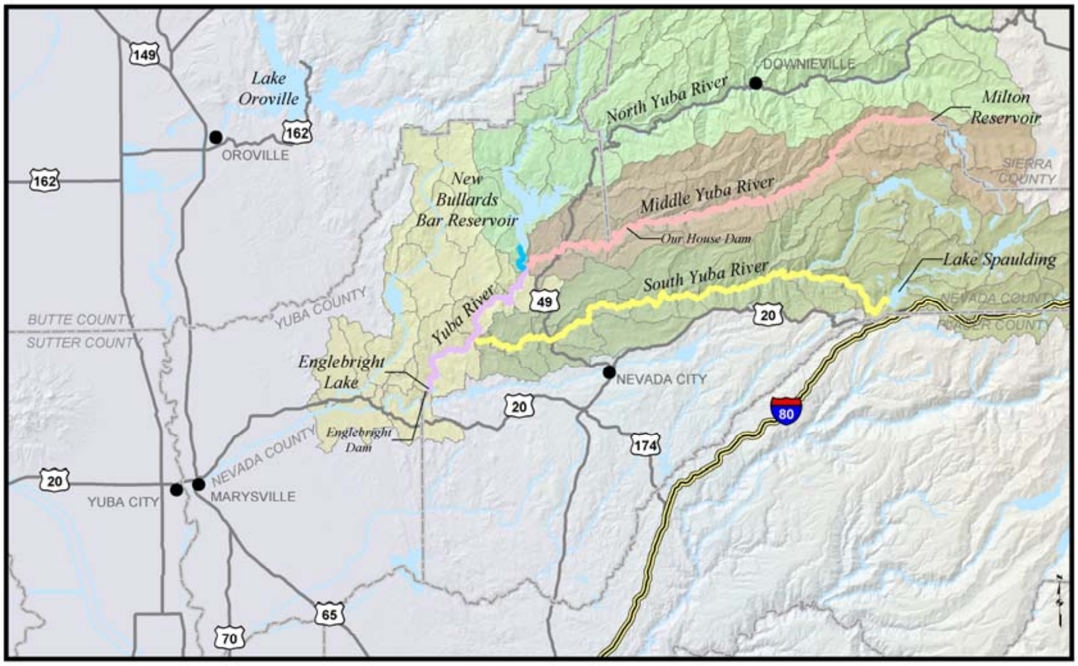

FIGURE 1-1
Upper Yuba River Watershed and Study Area

1.3 Species and Habitat Requirements

All species require specific physical and biological conditions in order to survive and reproduce. Collectively, these conditions are considered “habitat.” Often, throughout the year and over time, these conditions change as a result of fluctuations in flow, local weather, and regional climate. Required habitat elements also change over the life cycle of the species, with different life history stages requiring different habitats. For species to complete their life cycle (i.e., survive and successfully reproduce), there must be adequate habitat for all life stages. A lack of required habitat elements for even one life-stage can preclude a species from completing its life cycle and, ultimately, threaten survival of the population.

For the introduction of Chinook salmon and steelhead into the upper Yuba River to be biologically feasible, suitable habitat conditions must exist for each fresh water life-history stage, leading to successful completion of each species’ life cycle. This section summarizes the life histories of Chinook salmon and steelhead and describes the general physical habitat requirements for each species’ freshwater life stage.

1.3.1 Life History

Chinook salmon and steelhead spend most of their lives in the ocean and migrate to freshwater to spawn. This type of life history is termed “anadromous.” Chinook salmon and steelhead belong to the family Salmonidae (members of which are referred to as “salmonids”); hence, Chinook salmon and steelhead are considered anadromous salmonids. Only the freshwater portion of Chinook salmon and steelhead life histories are described in detail below.

Chinook Salmon

Races (also called "runs") of Chinook salmon are designated by the time of year that adults migrate into the river. The Sacramento River basin contains four distinct runs of Chinook salmon: fall, late-fall, winter, and spring. The Yuba River, a sub-watershed in the Sacramento River basin, historically supported both fall-run and spring-run Chinook salmon. Access to the areas historically available to spring-run Chinook salmon in the Yuba River has been blocked by Englebright Dam. Currently, Chinook salmon return to the lower Yuba River at times characteristic of both fall-run and spring-run fish.

Chinook salmon have diverse life histories that are highly variable among races and geography. Fall-run Chinook salmon return to their natal streams in the fall, a few days or weeks before spawning. Spring-run Chinook salmon return to their natal streams in the spring and early summer, several months prior to spawning, and "hold" over the summer in deep pools before spawning in the late summer and fall. Spring-run Chinook salmon typically migrate into the upper reaches of a watershed, whereas fall-run Chinook salmon typically use the lower elevation reaches.

Chinook salmon do not feed following entry into freshwater or during their spawning migration. Spawning takes place in nests or "redds," which are constructed by females of the species in riffle areas, typically at the tail (downstream) end of pools. Eggs are deposited, fertilized, and covered with loose clean gravel. The developing eggs remain in the redds until hatching. Newly hatched alevin (fry with a yolk sac) emerge from the substrate, finish absorbing the remaining yolk sac, and disperse in the river. During a period of active feeding and growth, the fry continue to disperse, and settle into slower moving rearing habitats along the stream margin. Fall-run Chinook salmon in the Central Valley of California generally are "ocean-type" populations, migrating to ocean during the first year of life, often within three months after emergence. Spring-run Chinook salmon in the Central Valley are typically "stream-type" populations, spending several months in freshwater before migrating to the ocean as yearlings, although some young spring-run Chinook migrate shortly after hatching. For all races of Chinook salmon, adults die shortly after spawning.

Following several weeks or months of rearing, larger-sized juveniles begin an active emigration (i.e., downstream migration) and eventually enter estuaries as smolts (juveniles physiologically adapted for life in saltwater). Fall-run Chinook salmon smolts from the Sacramento River basin generally spend up to 2 months in the freshwater portion of the Sacramento-San Joaquin Delta estuary before migrating into the saltwater portion of the estuary and ocean. Once in the ocean, Chinook salmon migrate, feed, grow, and mature into adults, remaining oceanic for 2 to 4 years or more before entering fresh water and migrating into their natal streams to spawn. Figure 1-2 depicts the life cycle of anadromous salmonids (Chinook salmon and steelhead).

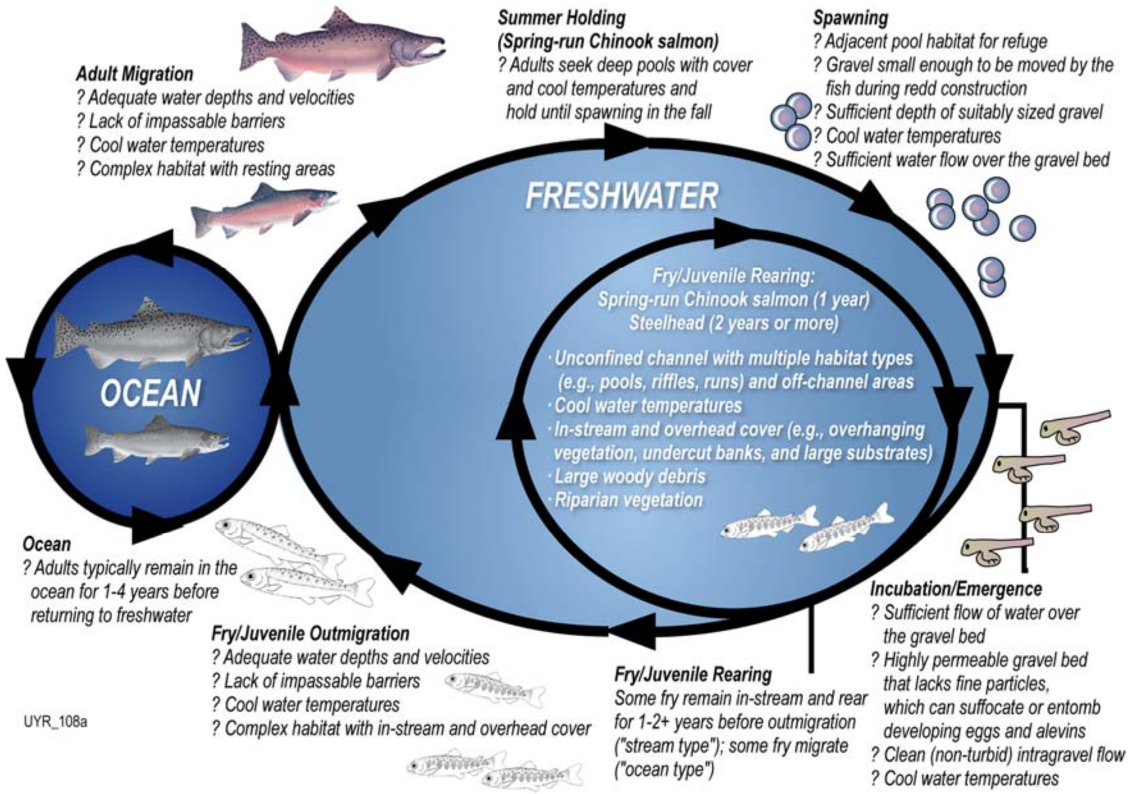

FIGURE 1-2
Generalized Salmonid Life Cycle

Steelhead

Steelhead, the anadromous (sea-going) form of rainbow trout, are found in Central Valley streams with almost the entire population restricted to the Sacramento River and its tributaries. Steelhead have a diverse life history that may be more variable than Chinook salmon, depending on race and geography. The steelhead life cycle is similar to that of Chinook salmon (see Figure 1-2). However, steelhead adults do not necessarily die following spawning and the juveniles typically rear for 2 years or more before actively migrating to the estuary and ocean as smolts. Once in the ocean, steelhead migrate, feed, grow, and mature into adults. They remain oceanic anywhere from 1 to 4 years before entering fresh water and migrating into their natal streams to spawn.

1.3.2 Key Habitat Requirements

Both Chinook salmon and steelhead require physical habitat in fresh water for adult migration and holding, spawning and egg incubation, fry and juvenile rearing, and smolt emigration. Adequate flows, water temperatures, water depths and velocities, appropriate spawning and rearing substrates, and the availability of cover and food are critical for successful completion each species' life cycle (see Figure 1-2).

Adult migration requires sufficient water depths and velocities to provide barrier-free passage, as well as suitable water temperatures. Compared to fall-run Chinook salmon and steelhead, adult spring-run Chinook salmon have an additional need for longer-term adult holding habitat, in which pool size and depth, temperature, and proximity to cover and spawning areas are important. Successful spawning requires suitable depths, water velocities, temperatures, and substrate sizes. Egg and alevin (yolk-sac fry) incubation requires suitable temperatures and adequate intra-gravel flow (i.e., gravel permeability) in the redds. Newly emerged alevins, fry, and juvenile salmon seek lower-velocity rearing habitats, with suitable substrates and water temperatures, and an adequate food supply. Because of their extended rearing period in fresh water, juvenile steelhead require suitable rearing habitat throughout the year. Dispersal of pre-smolts and active migration of smolts to the estuary and ocean require sufficient water depths and temperatures, adequate transport flows, and barrier-free passage.

Habitat needs for Chinook salmon and steelhead are generally similar, although steelhead differ somewhat in their freshwater habitat requirements. Specific habitat requirements for the various species and life stages and current habitat conditions in the upper Yuba River watershed are described in the following appendices to this report:

- Appendix B (Water Temperature Criteria of Chinook Salmon and Steelhead)
- Appendix C (Assessment of Adult Anadromous Salmonid Migration Barriers and Holding Habitats in the Upper Yuba River)
- Appendix D (Spawning Habitat Evaluation)
- Appendix E (Upper Yuba River Chinook Salmon and Steelhead Rearing Habitat Assessment)

CHAPTER 2

Analysis Approach

To identify the amount of thermally suitable habitat and develop rough predictions of the number of fish the habitat could possibly support, water temperatures were integrated with the physical habitat characteristics of the Middle and South Yuba rivers using a step-wise approach. A graphical representation of this approach is presented in Figure 2-1. The approach was developed to assess habitat conditions observed under current water operations, but was also applied to assess habitat under conditions of increased flow using results from the water temperature modeling.

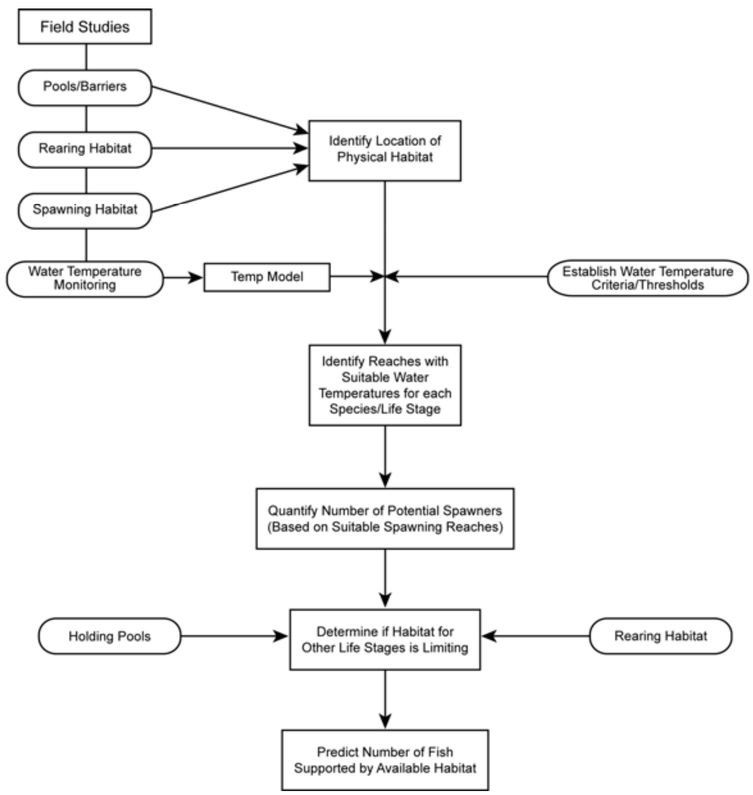

FIGURE 2-1
Flow Chart Depicting the Systematic Approach to Evaluation of Habitat Suitability and Predicted Numbers of Fish Supported

To define the extent of thermally suitable habitat, water temperatures observed during the water temperature monitoring program (Appendix F) were compared to the water temperature tolerances of the various life stages of Chinook salmon and steelhead during the time the life stages would be found in the upper Yuba River watershed (Table 2-1). The upper limit of the "suboptimal" temperature range was used to define the threshold of thermal suitability for each species' life stages. Reaches with water temperatures that remained below the upper suboptimal threshold were considered thermally suitable for the target species/life stage.

TABLE 2-1
Water Temperature Tolerance of Different Life Stages of Spring-run Chinook Salmon and Steelhead
See Appendix B for Literature Reviewed to Identify the Temperature Ranges

Species and Life Stage	Primary Time Period	Temperature: Optimal[a]	Temperature: Suboptimal[b]	Temperature: Chronic to Acute Stress[c]	Notes
Spring-run Chinook salmon					
Upstream migration	Apr–Jun	< 13.3°C (< 56°F)	13.3–18.3°C (56–65°F)	> 18.3°C (> 65°F)	Possible blockage or delay of upstream migration at temps > 13.3°C
Adult holding	mid Apr–late Sep	< 16°C (< 60.8°F)	16–19°C (60.8–66.2°F)	> 19°C (> 66.2°F)	thermal criteria are those used for Battle Creek spring Chinook
Spawning	Sep–Oct	< 13.3°C (< 56°F)	13.3–15.6°C (56–60°F)	> 15.6°C (> 60°F)	
Egg incubation	late Sep–Jan	< 12°C (< 54°F)	12–14.4°C (54–58°F)	> 14.4°C (>58°F)	
Fry and juvenile rearing and outmigration	mid Nov–Apr[d]	< 15.6°C (< 60°F)	15.6–18.3°C (60–65°F)	> 18.3°C (> 65°F)	
Winter steelhead					
Upstream migration/adult residence	Aug-Mar	< 11.1°C (< 52°F)	11.1–21°C (52–70°F)	> 21°C (> 70°F)	
Spawning	Jan–Apr	< 11.1°C (< 52°F)	11.1–12.8°C (52–55°F)	> 12.8°C (> 55°F)	Temperatures inferred from incubation temps
Egg incubation	Jan–early Jun	< 11.1°C (< 52°F)	11.1–12.8°C (52–55°F)	> 12.8°C (> 55°F)	
Fry and juvenile rearing and outmigration	Jan–Dec	< 18.3°C (< 65°F)	18.3–20°C (65–68°F)	> 20°C (> 68°F)	

[a] Feeding and growth occur; growth dependent on food availability. No sublethal or lethal effects.
[b] No direct mortality, but may result in a higher probability of diminished success (i.e., sublethal effects), especially at high end of range.
[c] Chronic exposure at the low end of the range results in sublethal effects, including reduced growth, reduced competitive ability, behavioral alterations, and increased susceptibility to disease. At higher temperatures in this zone, short-term exposure (minutes to days) results in death.
[d] Presumes that spring-run Chinook salmon in the Upper Yuba River basin would follow an "ocean-type" life history pattern, similar to the population in Butte Creek, and juveniles would not typically over-summer due to excessively high summer water temperatures.

Figure 2-2 provides an example of observed water temperatures in the Middle Yuba River during 2004 compared to the water temperature tolerance of the adult holding life stage of spring-run Chinook salmon. In this example, it is clear that the suboptimal water temperature threshold for adult holding (19 degrees Celsius [°C]) was exceeded at Wolf Creek (river mile [RM] 26) and locations downstream, but was not exceeded upstream between the box canyons (RM 37). The widely spaced water temperature monitoring locations provide a general indication of the extent of suitable water temperatures; a more precise estimate of the downstream extent of suitable water temperatures was needed to quantify the extent of thermally suitable habitat. To better define the downstream extent of thermally suitable habitat, the water temperature model developed for the upper Yuba River watershed (see Appendix A) was used to predict water temperatures at intermediate points between the widely spaced monitoring locations.

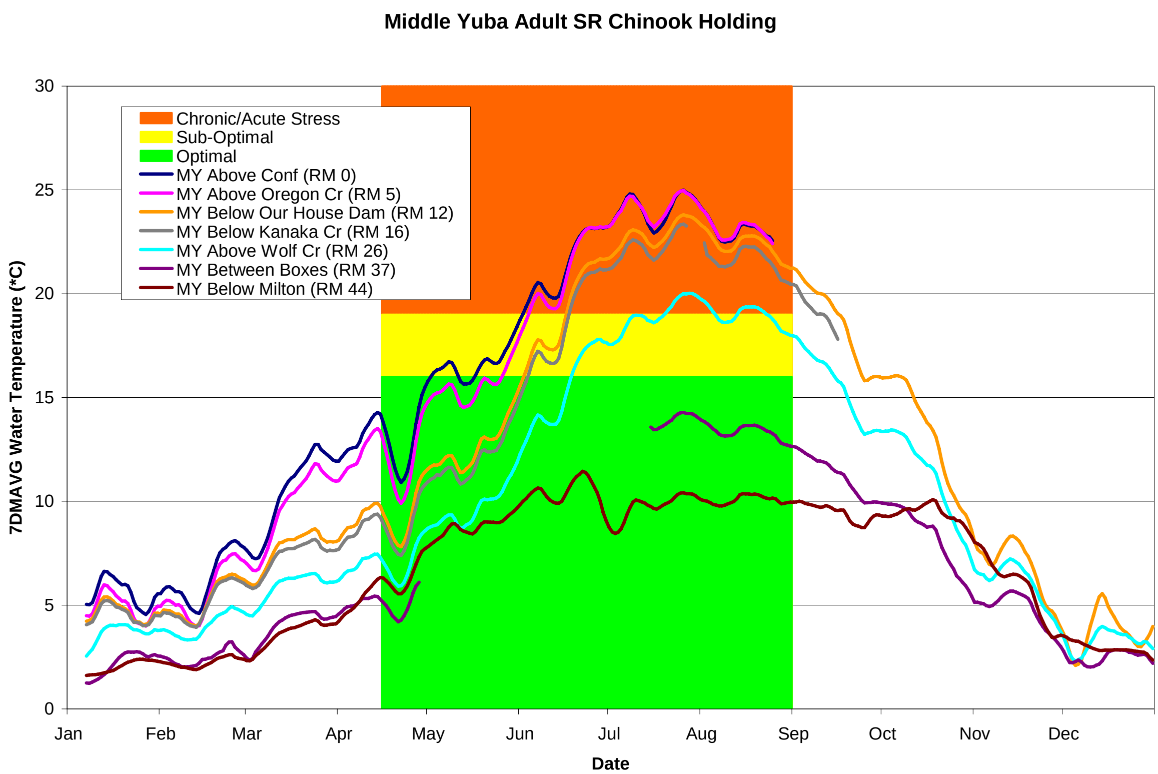

FIGURE 2-2
Observed Water Temperatures in the Middle Yuba River (2004) Compared to Water Temperature Tolerance of Holding Adult Spring-run Chinook Salmon (see Appendix B for description of temperature ranges)
Y-axis indicates the moving (running) 7-day average of the daily average water temperatures

Figure 2-3 provides an example of summer water temperatures predicted at locations intermediate to the monitoring locations (i.e., between Boxes and Wolf Creek) and compares the predicted values to the water temperature thresholds for holding adult spring-run Chinook salmon. In this example, the suboptimal water temperature threshold would not be exceeded in reaches upstream of Reach 230 (RM 28.8) with downstream locations having warmer water. The downstream extent of the thermally suitable reach for holding of adult spring-run Chinook salmon was identified as the downstream extent of Reach 230 (RM 28.8).

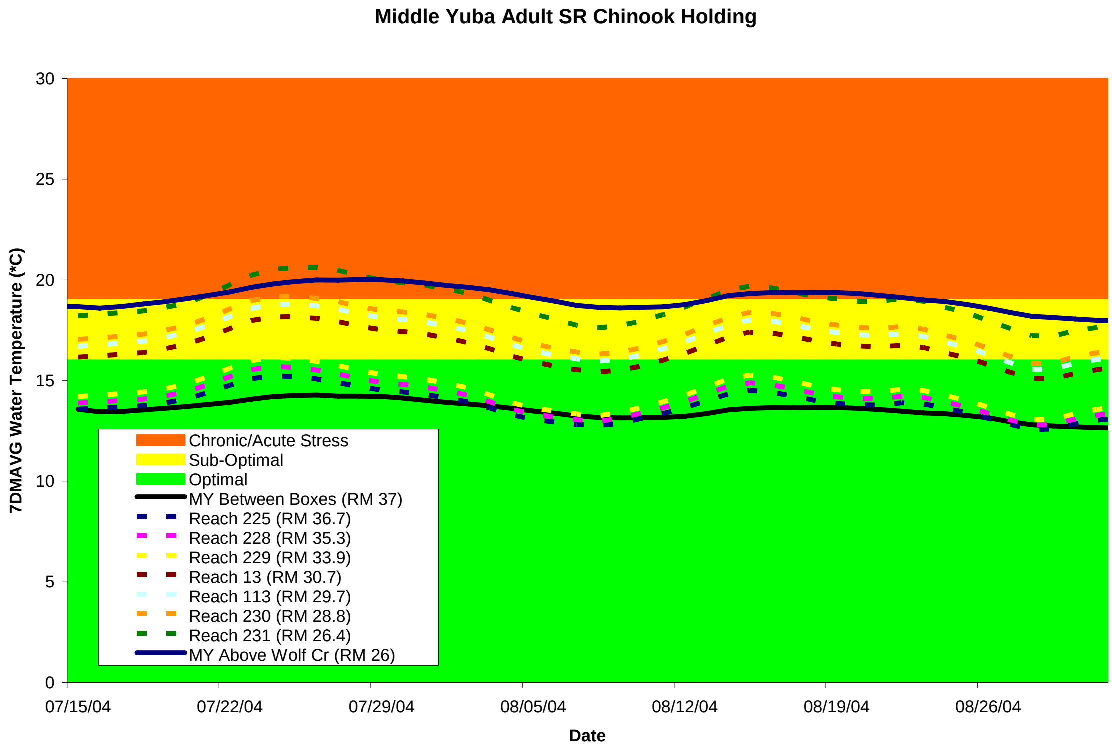

FIGURE 2-3
Predicted Water Temperatures in the Middle Yuba River Compared to Water Temperature Tolerance of Holding Adult Spring-run Chinook Salmon (see Appendix B for description of temperature ranges)
Y-axis indicates the moving (running) 7-day average of the daily average water temperatures

This process was used to determine the extent of thermally suitable river reaches for each species and life stage. The results for each life stage were integrated to identify the extent of each river that would support both species by providing physical habitat and water temperatures suitable for completion of the species' life cycle. For example, spring-run Chinook salmon must have suitable water temperatures during their upstream migration, adult holding, spawning/incubation, and rearing life stages (each with different water temperature thresholds) in order to complete their life cycle. Failure to find both suitable habitat and water temperatures during any one life stage would preclude successful completion of the life cycle and limit the feasibility of any introduction of that species into the upper Yuba River watershed. The integration of life stages for each species is discussed in greater detail in Chapters 3 and 4 for both current water operations and conditions of increased flows.

CHAPTER 3

Habitat Analysis: Current Water Operations

3.1 Thermally Suitable Reaches

Instream temperatures were monitored at several locations in the North, Middle and South Yuba rivers for the purpose of documenting temperatures in the rivers and providing the data necessary for developing a water temperature model. A full description of the methods and results of the instream temperature monitoring program is presented in Appendix F. The temperature monitoring data were compared to the temperature thresholds identified in Table 2-1 for Chinook salmon and steelhead in order to determine the river reaches that had suitable water temperatures for each species and life stage under current operations. The water temperature model described in Appendix A was used to predict water temperatures at intermediate points between the monitoring nodes, allowing the extent of thermally suitable reaches to be more accurately described. Only reaches available to spring-run Chinook salmon and steelhead (i.e., below the first total barrier to upstream migration) were assessed for thermal suitability. The following section presents the results of the analysis and identifies the thermally suitable reaches available for each life stage of spring-run Chinook salmon and steelhead.

3.1.1 Spring-run Chinook Salmon

Migration

Based on the known life history strategy of historic and existing spring-run Chinook salmon occurring within the Sacramento River watershed, adult spring-run Chinook salmon would be expected to migrate through the Middle and South Yuba rivers during the spring and early summer when water temperatures are typically low. Figures 3-1 and 3-2 show average water temperatures in the Middle and South Yuba rivers during 2004 compared to the temperature tolerances of migrating adult spring-run Chinook salmon. Water temperatures at this time generally remained below the suboptimal threshold for migration (18.3°C) in all reaches of the Middle Yuba River above Our House Dam and above Poorman Creek on the South Yuba River until late in the migration period. Water temperatures in the lower reaches of both rivers exceeded the suboptimal threshold during the later portion of the migration period (June). However, water temperatures were suitable for the majority of the expected migration period, suggesting that water temperature during the migration period would not limit the distribution of spring-run Chinook salmon in the upper Yuba River watershed.

Middle Yuba Adult SR Chinook Migration

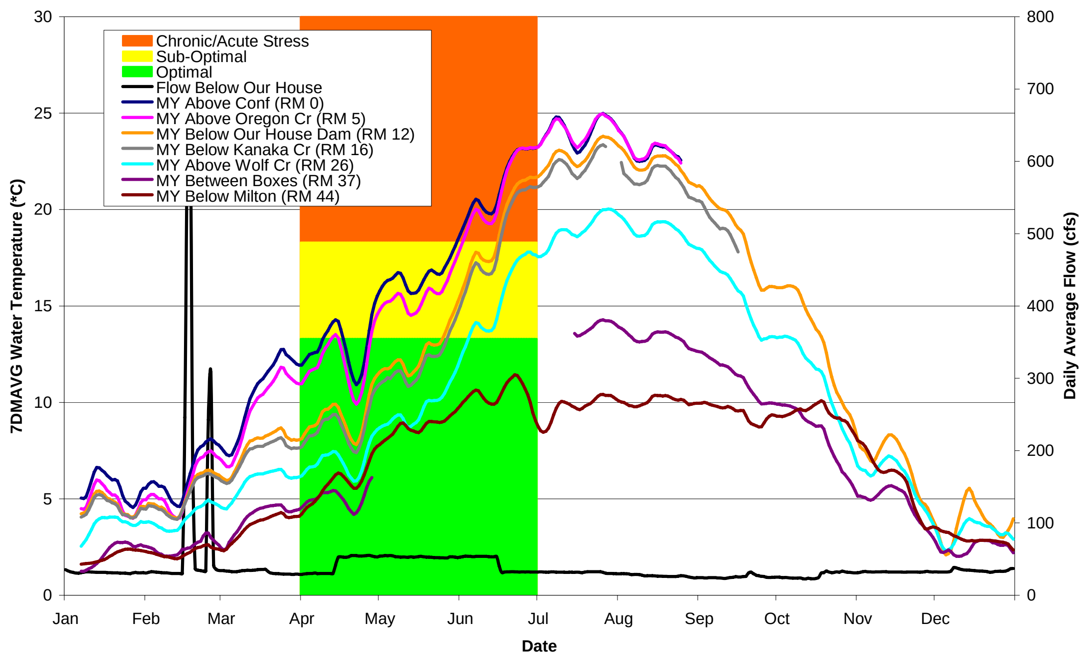

FIGURE 3-1
Average Water Temperatures and Flow During the Adult Spring-run Chinook Salmon Migration Period in the Middle Yuba River Under Current Operations (2004)

South Yuba River Adult SR Chinook Migration

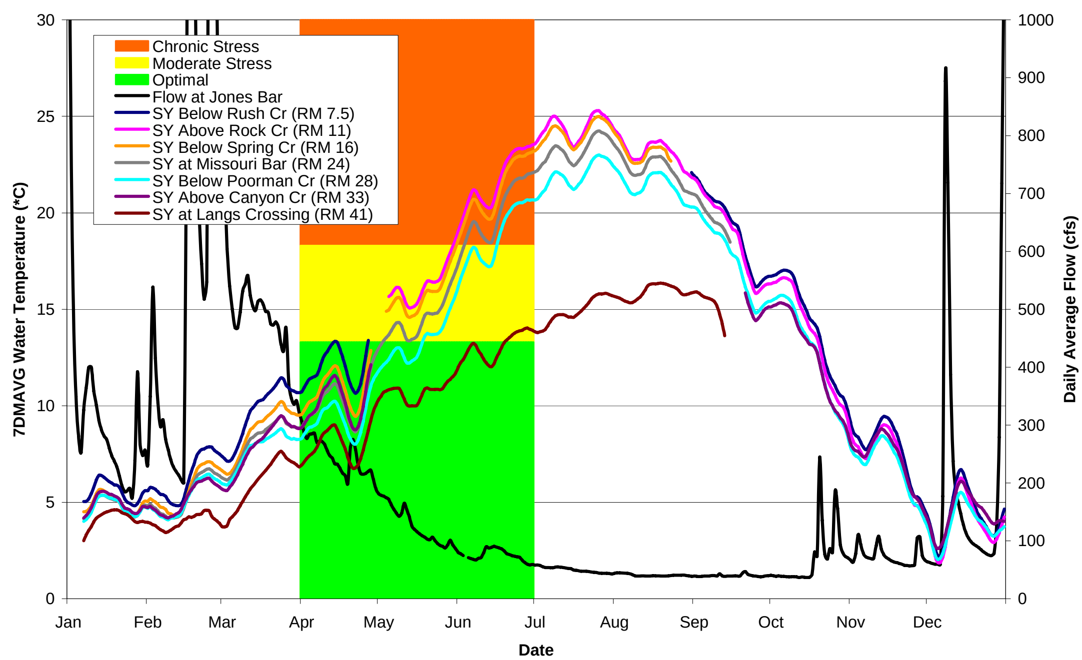

FIGURE 3-2
Average Water Temperatures and Flow During the Adult Spring-run Chinook Salmon Migration Period in the South Yuba River Under Current Operations (2004)

Adult Holding

Water temperatures during the adult holding period (mid-April to September) are of greater concern than those during the migration period because this time span encompasses the highest temperatures experienced during the year. Adult spring-run Chinook salmon must survive this period to spawn in the fall. On the Middle Yuba River, water temperatures remained below the suboptimal threshold for adult holding (19°C) in areas upstream of approximately Wolf Creek during 2004 (Figure 3-3). The thermally suitable reach for holding spring-run Chinook salmon, as determined using the water temperature model, was identified as extending downstream of Milton Reservoir to approximately RM 28.8 (upstream of Wolf Creek). A depiction of the thermally suitable reaches identified for adult holding within the Middle and South Yuba rivers is presented in Figure 3-4. This figure also indicates the location of total barriers to upstream migration at RM 34.4 on the Middle Yuba River and RM 35.4 on the South Yuba River. On the South Yuba River, suitable holding temperatures were predicted to occur over a short distance downstream from Langs Crossing (the uppermost monitoring location), and this location is above the first natural barrier to upstream fish passage. Access to these reaches for adult spring-run Chinook salmon would therefore be blocked by the barrier.

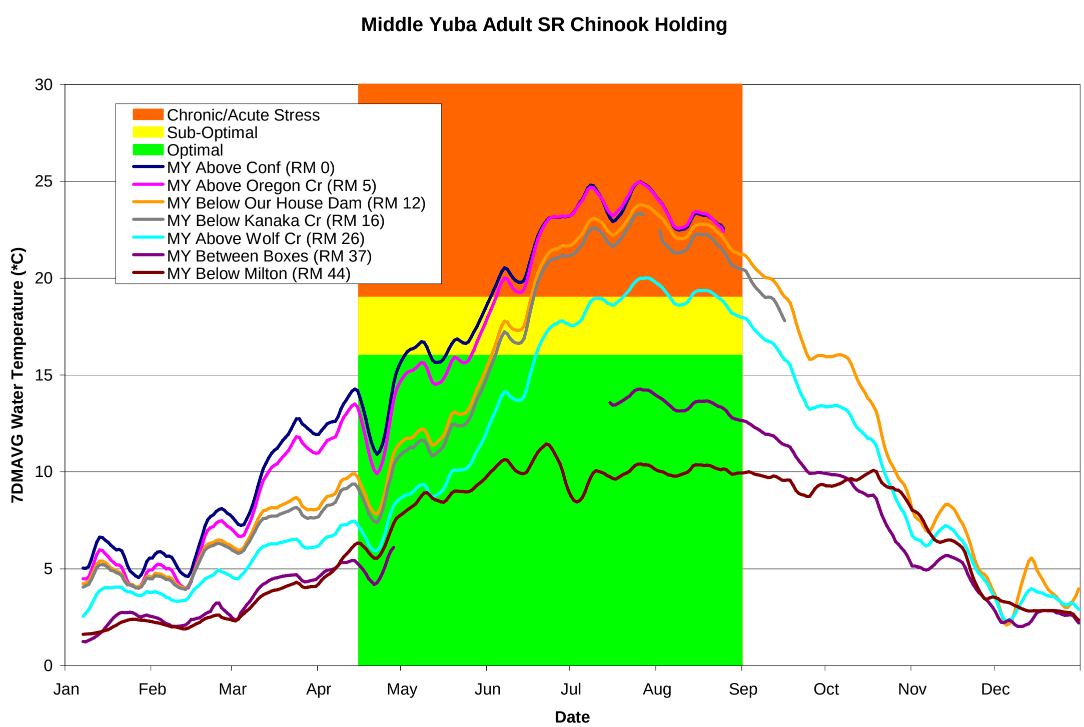

FIGURE 3-3
Average Water Temperatures During the Adult Spring-run Chinook Salmon Holding Period in the Middle Yuba River Under Current Operations (2004)

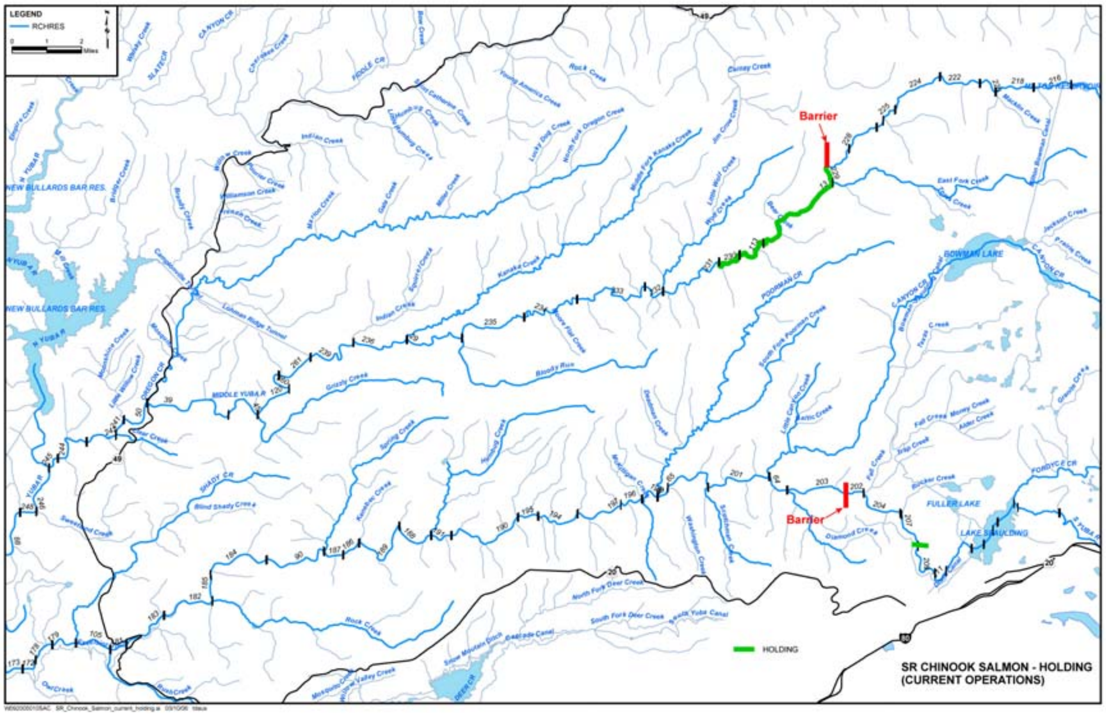

FIGURE 3-4
River Reaches with Suitable Water Temperatures for Adult Spring-run Chinook Salmon Holding (in green) in the Middle and South Yuba Rivers[1] Under Current Operations (2004)
Hatch marks indicate the reaches used in the water temperature model.

Spawning and Egg Incubation

Spring-run Chinook salmon spawn during the fall, generally from September through October, and eggs incubate in the gravel over the winter. Chinook salmon may delay spawning until water temperatures are suitable, which can result in reduced egg viability or mortality of adults prior to spawning. The suboptimal threshold temperature for spawning (15.6°C) is higher than for incubation (14.4°C). For the analysis, the lower temperature threshold was used in order to identify the extent of reaches with suitable water temperatures for both spawning and egg incubation. The lower temperature threshold was used because eggs begin incubating the moment they are placed in the gravel (spawned) and could experience mortality at the higher threshold temperature for spawning, depending on the extent and duration of temperatures above the incubation threshold.

As shown in Figure 3-5, water temperatures that are suitable for incubation in early September were predicted to occur upstream of approximately RM 33.8 (near East Fork Creek) on the Middle Yuba River in 2004 and extended farther downstream later in the spawning and incubation period as water temperatures declined throughout the river. The dates on Figure 3-5 indicate the location of the downstream extent of suitable water temperatures predicted on (and before) these dates. Suitable water temperatures for incubation on the South Yuba River were predicted to occur only a short distance downstream of Langs Crossing until later in the spawning and incubation period. On the South Yuba River, the first total barrier to upstream fish passage is located downstream of reaches with predicted water temperatures suitable for spawning and incubation during

[1] As noted in the text, the natural barrier on the South Yuba River is downstream of reaches predicted to have suitable water temperatures and would block access to these reaches.

most of September; therefore, no habitat with suitable water temperatures would be available for spawning or incubation of spring-run Chinook salmon until later in the year. By October 1, water temperatures were predicted to be suitable for spawning and incubation throughout the South Yuba River, at least as far downstream as Missouri Bar (RM 24) (see Figure 3-5).

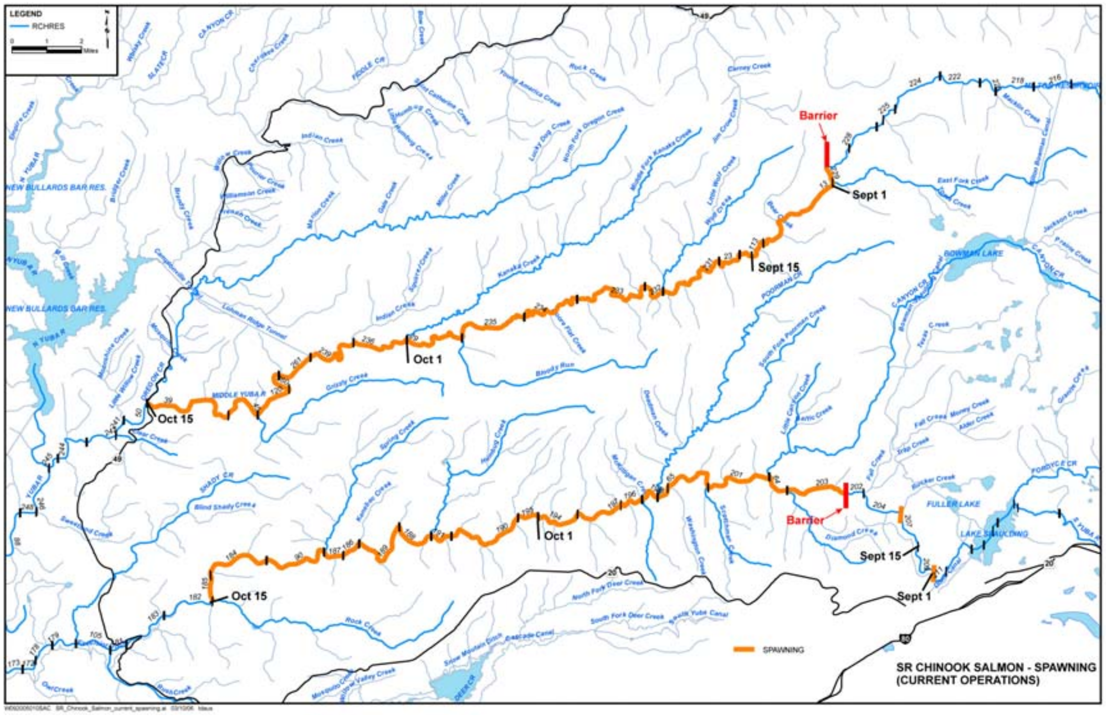

FIGURE 3-5
River Reaches with Suitable Water Temperatures for Spring-run Chinook Salmon Spawning and Incubation (in orange) in the Middle and South Yuba Rivers Under Current Operations (2004)

Rearing and Outmigration

“Ocean-type” spring-run Chinook salmon migrate shortly after emergence (as fry) while “stream-type” juveniles rear over the summer and migrate downstream the following year. Fry that migrate early would not be subjected to the high summer water temperatures observed in the upper Yuba River watershed. Chinook salmon juveniles that remained in the river over the summer would be subjected to elevated stream temperatures. As shown in Figures 3-6 and 3-7, water temperatures in 2004 during the typical ocean-type fry rearing period (mid-November through March) were well below the threshold considered suitable for rearing (18.3°C) in all reaches of the Middle and South Yuba rivers. On the Middle Yuba River, water temperatures were predicted to remain below the suboptimal threshold for rearing upstream of approximately RM 30.7 (over 4 miles upstream of Wolf Creek) during the hottest part of the summer (Figure 3-8). On the South Yuba River, suitable temperatures for rearing were predicted to occur only a short distance downstream of Langs Crossing, but the first total barrier to upstream fish passage is located downstream of reaches with suitable water temperatures for rearing during the summer. Therefore, on the South Yuba River, no habitat with suitable water temperatures for rearing would be available to spring-run Chinook salmon during the summer (see Figure 3-8).

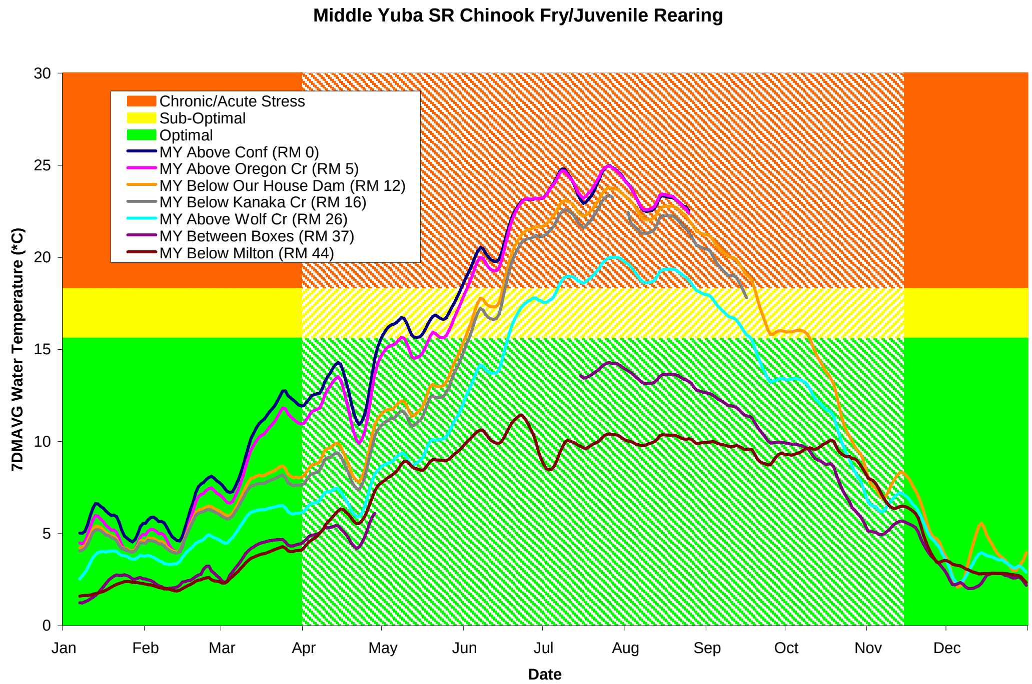

FIGURE 3-6
Average Water Temperatures During the Spring-run Chinook Salmon Rearing Period in the Middle Yuba River Under Current Operations (2004)
Solid area indicates the typical ocean-type fry rearing period while the hatched portion represents the summer rearing period for stream-type juveniles

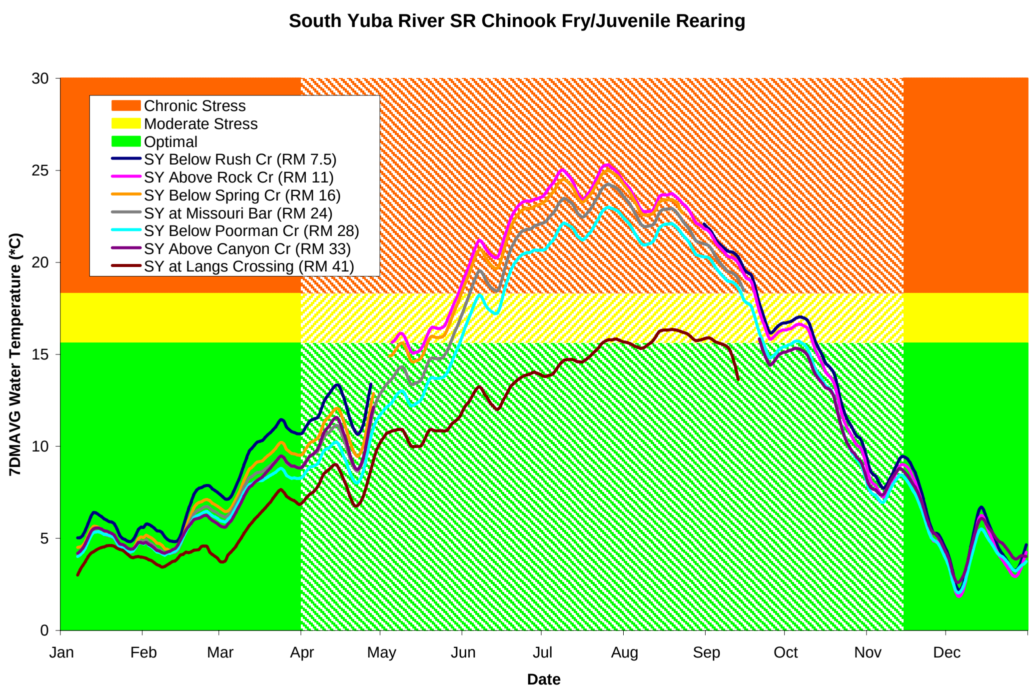

FIGURE 3-7
Average Water Temperatures During the Spring-run Chinook Salmon Rearing Period in the South Yuba River Under Current Operations (2004)
Solid area indicates the typical ocean-type fry rearing period while the hatched portion represents the summer rearing period for stream-type juveniles.

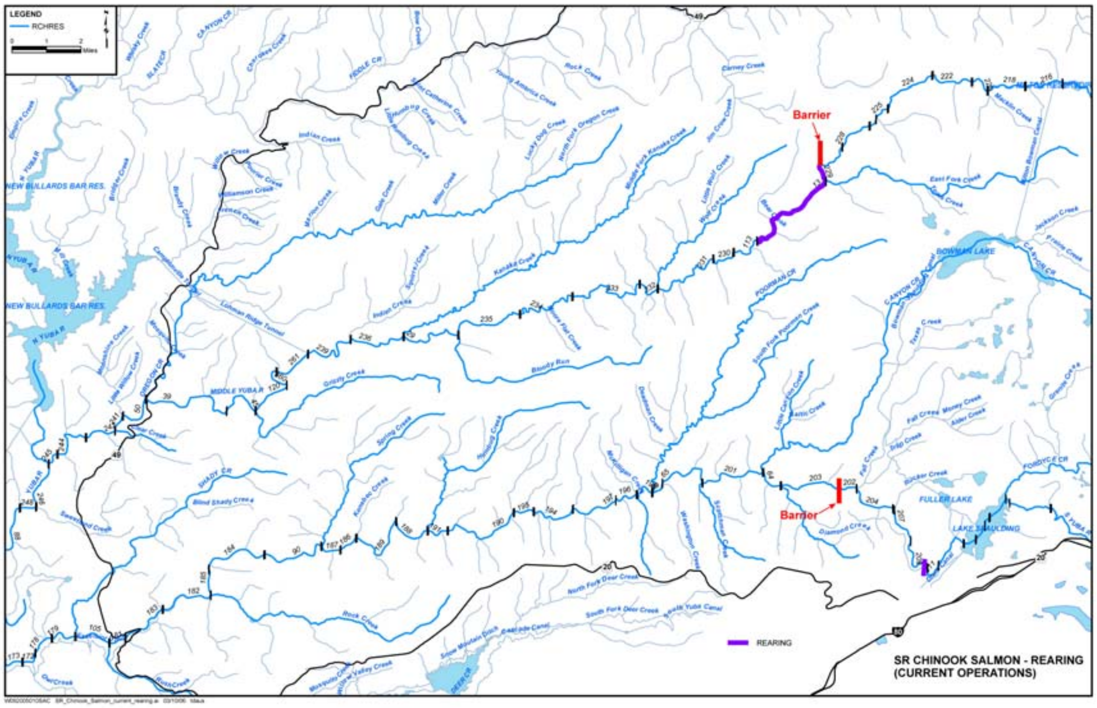

FIGURE 3-8
River Reaches with Suitable Water Temperatures for Spring-run Chinook Salmon Summer Rearing (in purple) in the Middle and South Yuba Rivers[2] Under Current Operations (2004)

Water temperatures during the typical outmigration period (March to June) remained below the critical threshold throughout the Middle and South Yuba rivers in 2004 until the later portion of the migration period. To avoid chronic or acute stress due to elevated water temperatures, Chinook salmon fry would need to leave the Middle Yuba River by the end of May and by mid-May on the South Yuba River. Based on observed emigration patterns for juvenile spring-run Chinook salmon inhabiting a warmer Sacramento River tributary (Butte Creek), many juvenile spring-run Chinook salmon may outmigrate as fry before temperatures become unsuitable (Ward and McReynolds 2001; Ward et al. 2004a, 2004b). Based on water temperatures observed in 2004, juveniles that remained in the river over the summer would find suitable water temperatures in the upstream reaches of the Middle Yuba River identified in Figure 3-8.

3.1.2 Steelhead

Migration

Steelhead would migrate through the Middle and South Yuba rivers primarily during the fall and winter when water temperatures are typically low. Water temperatures at this time generally remain below the suboptimal threshold for migration (21.0°C) in all reaches of the Middle Yuba River above Kanaka Creek and above Poorman Creek on the South Yuba River. Water temperatures in the lower reaches of both rivers exceeded the threshold only during the early portion of the migration period (August) in 2004. Few steelhead would likely be

[2] As noted in the text, the natural barrier on the South Yuba River is downstream of reaches predicted to have suitable water temperatures and would block access to these reaches.

migrating upstream at this time because the peak migration time for Central Valley steelhead is generally later in the fall. Steelhead migrating during the early portion of the migration period would be subject to elevated water temperatures that could result in mortality or reduced egg viability, but it is more likely that adult steelhead would delay migration until later when water temperatures are generally suitable. Timing of annual upstream adult migration is influenced by weather (rainfall), hydrologic conditions, and water temperatures. These factors suggest that water temperatures during the migration period would not limit the distribution of steelhead in the upper Yuba River watershed.

Spawning and Egg Incubation

Steelhead spawn during the winter and spring, generally from January through April when water temperatures are naturally low. Egg incubation can occur through mid-June. Figure 3-9 indicates the predicted downstream extent of suitable water temperatures for spawning and incubation of steelhead. Dates indicate that suitable water temperatures were predicted on or before the indicated date at that location. Based on water temperatures observed in 2004, suitable temperatures for spawning and egg incubation (less than 12.8°C) would be available in all reaches of the Middle Yuba River during the early portion of the spawning and incubation period. Stream reaches upstream of approximately RM 22.7 (between Kanaka and Wolf creeks) were predicted to have suitable water temperatures during the entire spawning and incubation period. Before June, water temperatures suitable for incubation were predicted to occur at least as far downstream as Kanaka Creek on the Middle Yuba River. Before this date, suitable incubation temperatures were predicted to extend several miles downstream of this point. On the South Yuba River, suitable temperatures for spawning and incubation would be found only a short distance downstream of Langs Crossing except early in the incubation period. A total barrier to upstream fish passage is located downstream of reaches where water temperatures would be suitable for incubation prior to June; therefore, no habitat with suitable water temperatures would be available for spawning or incubation of steelhead, except perhaps for fish that spawn early in the year. Before June, water temperatures suitable for incubation were predicted to extend as far downstream as Missouri Bar on the South Yuba River (see Figure 3-9).

Rearing and Outmigration

Juvenile steelhead can spend up to 3 years in freshwater before outmigrating to the ocean, but 1 to 2 years is more typical. Given this life history strategy, juvenile steelhead would be subject to elevated summer water temperatures in portions of the upper Yuba River watershed. As indicated in Figure 3-10, water temperatures observed during the summer of 2004 exceeded the suboptimal temperature threshold for rearing (20.0°C) in all reaches of the Middle Yuba River downstream of Wolf Creek. Analysis using the water temperature model identified the downstream extent of the thermally suitable reach for rearing steelhead at approximately RM 25.6 (about 1 mile below Wolf Creek) (Figure 3-11). On the South Yuba River, suitable temperatures for rearing during the summer were predicted only a short distance downstream of Langs Crossing. As with spawning and egg incubation, the total barrier to upstream fish passage located downstream of reaches with suitable water temperatures would preclude the use of these reaches for summer rearing (see Figure 3-11). Results of the water temperature monitoring, combined with modeling results, suggest that juvenile steelhead rearing below RM 25.6 on the Middle Yuba and throughout the South Yuba River would be subjected to elevated water temperatures and would likely experience chronic or acute effects, including mortality.

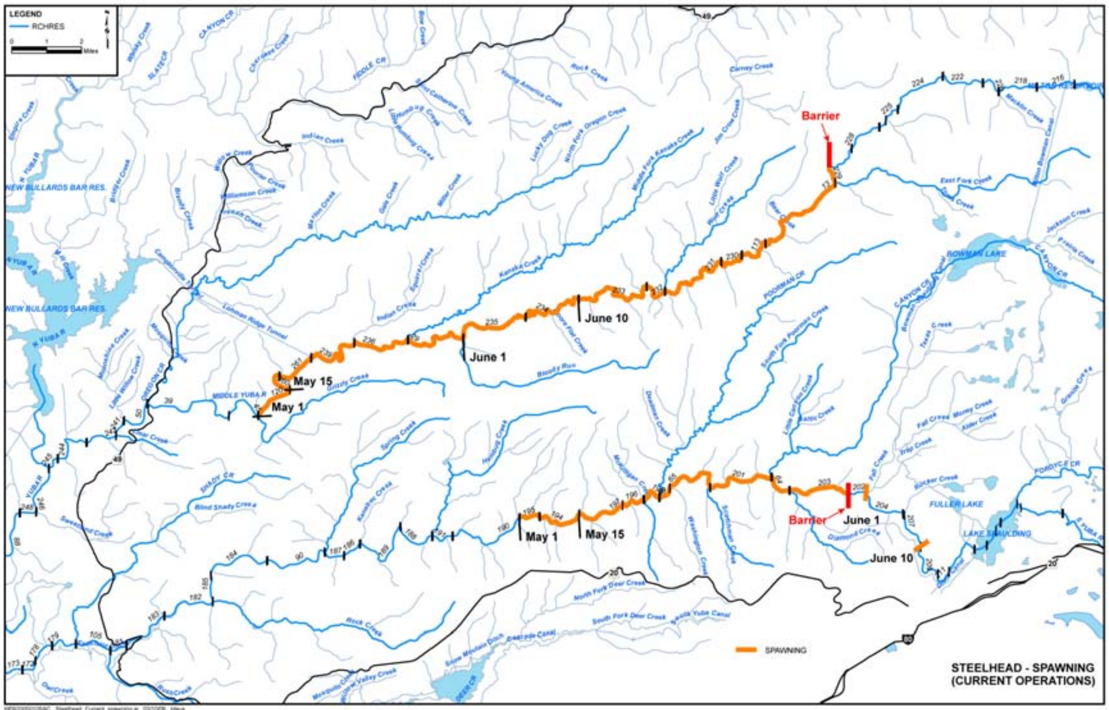

FIGURE 3-9
River Reaches With Suitable Water Temperatures for Steelhead Spawning and Incubation (in orange)
in the Middle and South Yuba Rivers Under Current Operations (2004)
Hatch marks indicate the reaches used in the water temperature model

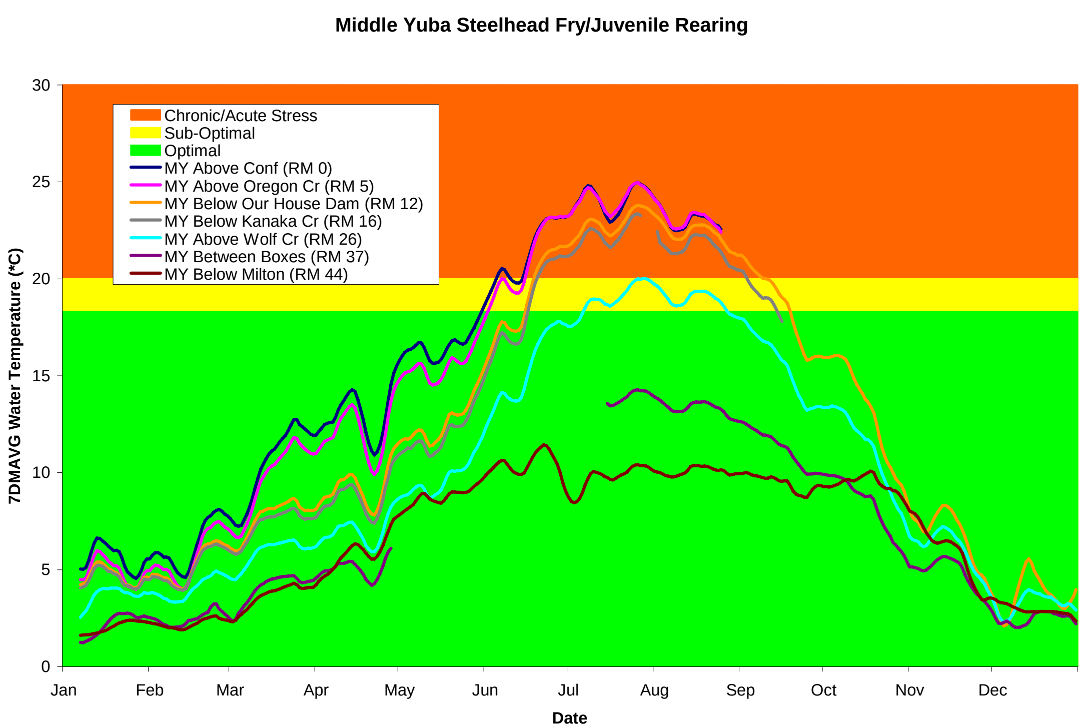

FIGURE 3-10
Average Water Temperatures During the Steelhead Rearing Period
in the Middle Yuba River Under Current Operations (2004)

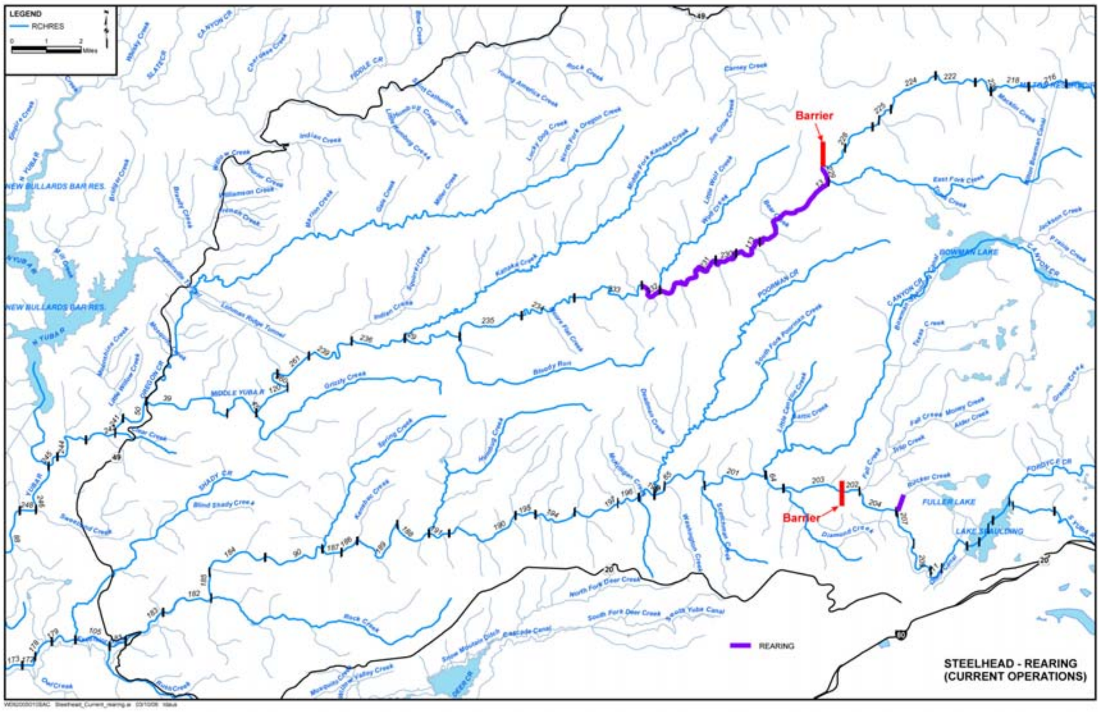

FIGURE 3-11
River Reaches with Suitable Water Temperatures for Steelhead Summer Rearing (in purple)
in the Middle and South Yuba Rivers[3] Under Current Operations (2004)

3.1.3 Fall-run Chinook Salmon

Fall-run Chinook salmon typically do not migrate as far upstream as spring-run Chinook salmon, and prefer to spawn at lower elevations where fall and winter flows provide adequate depths and velocities in larger mainstem rivers. The extent to which fall-run Chinook salmon would migrate upstream beyond Englebright Dam is unknown. However, fall-run Chinook salmon likely would use some of the lower portions of the Middle and South Yuba rivers if water temperatures were suitable and adequate spawning gravels were available.

To evaluate whether the available habitat for fall-run Chinook salmon upstream of Englebright Dam would have suitable water temperatures, observed and modeled water temperatures during the spawning and incubation life stage (November to June) were compared to the suboptimal threshold temperature for incubating Chinook salmon (14.4°C). Observed water temperatures during the typical fall-run Chinook salmon spawning and incubation period suggest that water temperatures during this time would be suitable for spawning and incubation of Chinook salmon throughout both the Middle and South Yuba rivers (see Appendix F). It is difficult to predict how far upstream fall-run Chinook salmon would migrate in these rivers for spawning, but it appears that they would have both suitably-sized spawning gravels and suitable water temperatures available at the appropriate time. In order to avoid unsuitable summer rearing temperatures, juvenile

---

[3] As noted in the text, the natural barrier on the South Yuba River is downstream of reaches predicted to have suitable water temperatures and would block access to these reaches.

fall-run Chinook salmon using the upper Yuba River watershed would need to exhibit the ocean-type life history (which is a strategy typical of fall-run) and leave the lower reaches of the rivers before temperatures become unsuitable for summer rearing.

3.2 Number of Chinook Salmon and Steelhead Redds

3.2.1 Spring-run Chinook Salmon

Figure 3-12 shows the linear extent of thermally suitable habitat predicted for three life stages of spring-run Chinook salmon using the water temperature model developed for the upper Yuba River watershed. The results of the analysis, based on temperature and hydrologic conditions in 2004, suggest that thermally suitable habitat for spring-run Chinook salmon on the Middle Yuba River would extend approximately 5.6 miles downstream of the natural barrier at RM 34.4 under current operations. The lower boundary of this reach is located at the downstream extent of habitat with suitable temperatures for adult holding (≤ 19°C) because it was assumed that adult spring-run Chinook salmon would continue to hold in this area until water temperatures became suitable for spawning, and most rearing spring-run Chinook salmon fry would leave the river before summer water temperatures exceed their temperature tolerance. Figure 3-13 shows the linear extent of thermally suitable habitat and cumulative number of spring-run Chinook salmon redds potentially supported below the barrier to upstream fish passage on the Middle Yuba River. Based on the analysis of spawning habitat (Appendix D), approximately 240 spring-run Chinook salmon redds could be supported by the available spawning habitat in the approximately 5.6 miles considered thermally suitable in the Middle Yuba River.

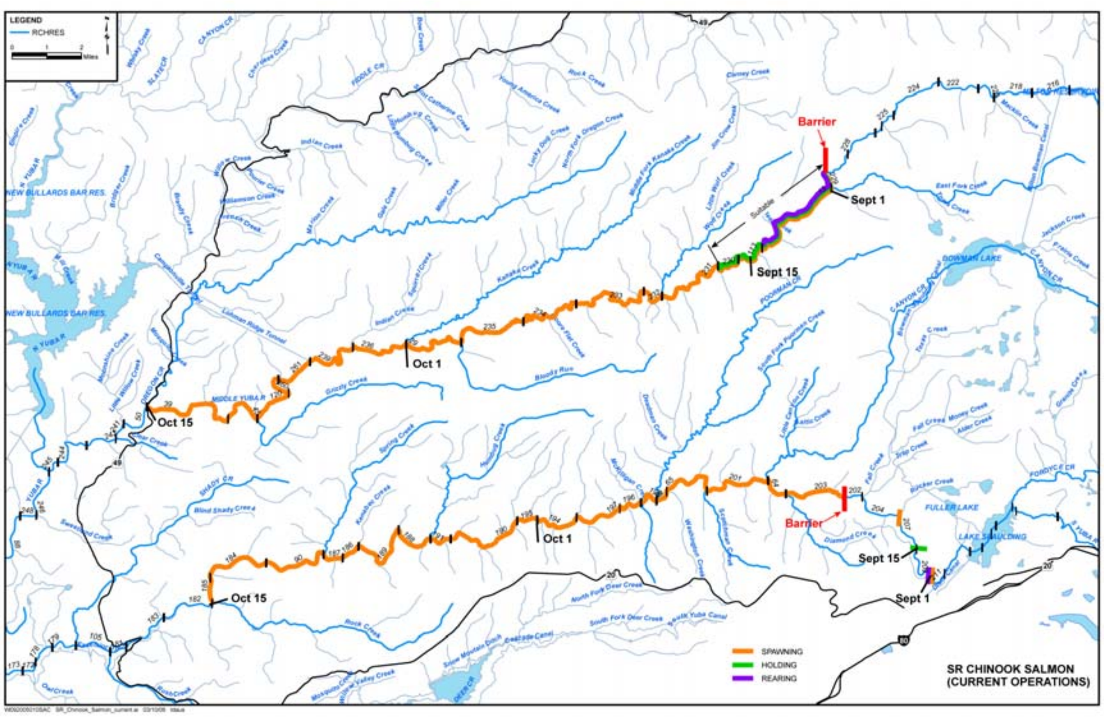

FIGURE 3-12
River Reaches with Suitable Water Temperatures for Spring-run Chinook Salmon in the Middle and South Yuba Rivers Under Current Operations (2004)

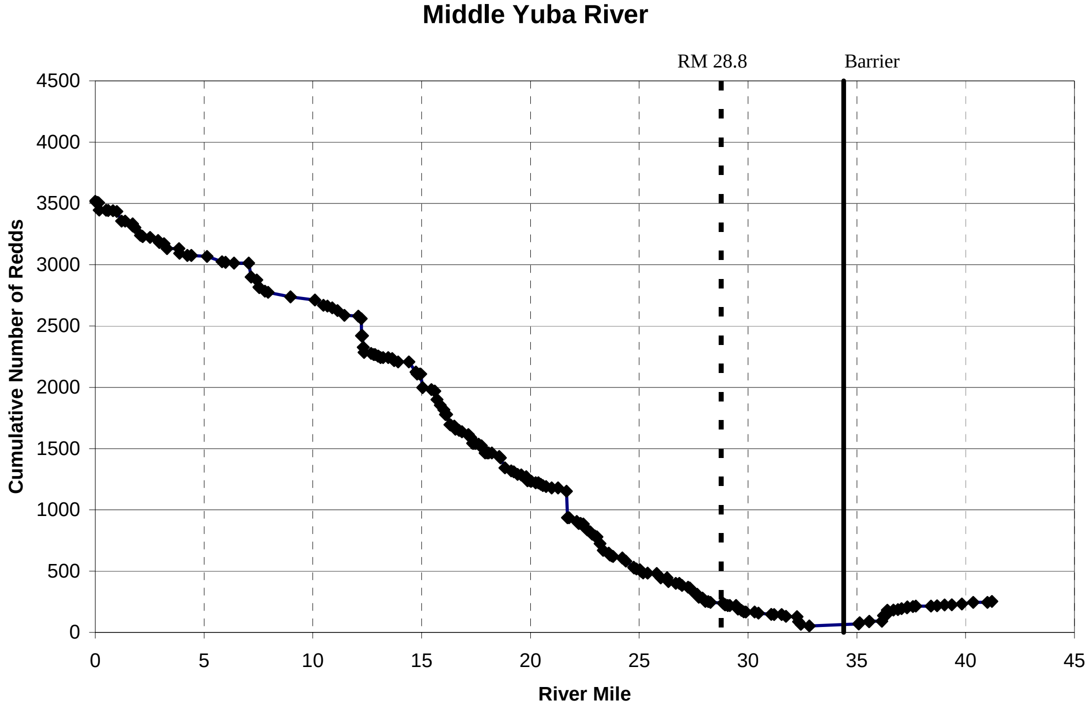

FIGURE 3-13
Downstream Extent of Thermally Suitable Habitat and Cumulative Number of Spring-run Chinook Salmon Redds Potentially Supported Below the First Total Barrier (RM 34.4) in the Middle Yuba River Under Current Operations

Assuming one female Chinook salmon per redd and a sex ratio of 1:1, it was predicted that approximately 480 spring-run Chinook salmon could spawn in the available habitat considered thermally suitable in the Middle Yuba River. This prediction could be conservative because:

- Potential spawning habitat only included pool tails that were visible from the aerial video and field surveys
- Redd density was adjusted downward for small gravel sizes and low permeability
- Redd density was adjusted downward based on quality of adjacent pool habitat
- Redd density was adjusted downward to account for the effects of redd superimposition
- Redd density used in the analysis was based on observed densities for fall-run Chinook salmon in the Stanislaus River (see Appendix D); redd density for spring-run Chinook salmon in other streams (e.g., Butte Creek) may be higher than assumed for the upper Yuba River watershed, suggesting that even more redds/adults could be supported

Because water temperatures in the South Yuba River downstream of the natural barrier to upstream fish passage were predicted to be above the suboptimal threshold for holding of adult spring-run Chinook salmon, no area with suitable water temperatures for completion of the Chinook salmon life cycle was identified. Based on water temperatures in 2004, high summer water temperatures in the South Yuba River would likely preclude establishment of a spring-run Chinook salmon population. However, further study of the temperature of water released into the South Yuba River from Lake Spaulding and refinement of the temperature model could influence this preliminary conclusion.

3.2.2 Steelhead

As shown in Figures 3-9 and 3-11, reaches that would have suitable spawning and incubation temperatures generally extend farther downstream than reaches that would have suitable rearing temperatures. Because steelhead juveniles must rear for at least one year in freshwater (typically two years) to complete the rearing phase of their life cycle, it is appropriate to identify the downstream extent of thermally suitable habitat for steelhead based on the juvenile rearing life stage. The results of the analysis, based on temperature and hydrologic conditions in 2004, suggest that on the Middle Yuba River, thermally suitable habitat for steelhead would extend approximately 8.8 miles downstream of the natural barrier to upstream migration at RM 34.4 to approximately RM 25.6 (below Wolf Creek) (Figure 3-14). In a field survey documenting rainbow trout distribution in the upper Yuba River watershed, rainbow trout were found in areas downstream of this point (a full description of the study is presented in Appendix G). Assuming rainbow trout are surrogates for juvenile steelhead, the presence of rainbow trout may indicate that steelhead rearing could occur farther downstream than predicted; however, insufficient field evidence is available to dispute the published temperature tolerance for steelhead juveniles used in establishing this boundary. Figure 3-15 shows the linear extent of thermally suitable habitat and cumulative number of steelhead redds potentially supported in the Middle Yuba River. Based on the analysis of spawning habitat (Appendix D), approximately 320 steelhead redds could be supported in the approximately 8.8 miles considered thermally suitable for steelhead in the Middle Yuba River.

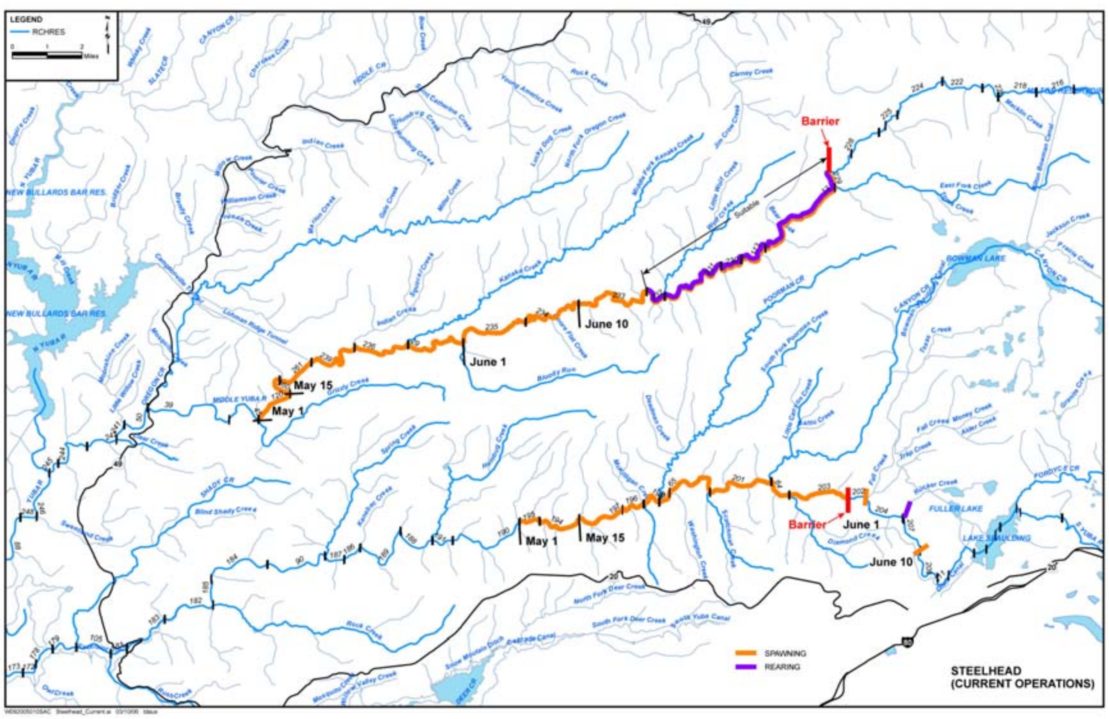

FIGURE 3-14
River Reaches with Suitable Water Temperatures for Steelhead in the Middle and South Yuba Rivers Under Current Operations (2004)

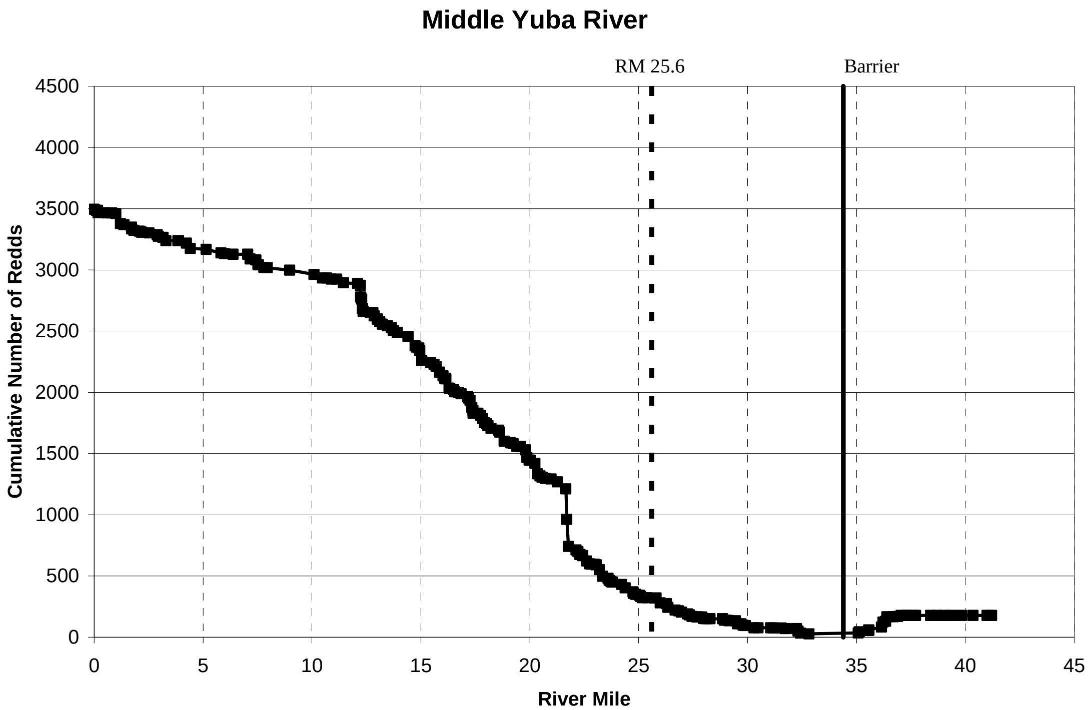

FIGURE 3-15
Downstream Extent of Thermally Suitable Habitat and Cumulative Number of Steelhead Redds Potentially Supported Below the First Total Barrier (RM 34.4) in the Middle Yuba River Under Current Operations

Assuming one female steelhead per redd and a sex ratio of 1:1, approximately 640 steelhead could spawn in the available habitat considered thermally suitable in the Middle Yuba River under current water operations. This prediction could be conservative because:

- Potential spawning habitat only included pool tails that were visible from the aerial video and field surveys
- Redd density was adjusted downward for small gravel sizes and low permeability
- Redd density was adjusted downward based on quality of adjacent pool habitat
- Redd density was adjusted downward to account for the effects of redd superimposition
- Redd density used in the analysis was based on a modification of the density used for spring-run Chinook salmon (see Appendix D); potential redd density for steelhead may be higher than assumed for the upper Yuba River watershed

Because predicted water temperatures in the South Yuba River downstream of the natural barrier to upstream fish passage were predicted to be above the suboptimal threshold for rearing juvenile steelhead, no area with both suitable habitat and suitable water temperatures for completion of the steelhead life cycle was identified. Based on water temperatures in 2004, high summer water temperatures in the South Yuba River would likely preclude establishment of a steelhead population. However, as previously described for spring-run Chinook salmon, further study of the temperature of water released into the South Yuba River from Lake Spaulding and refinement of the temperature model could influence this preliminary conclusion.

3.2.3 Fall-run Chinook Salmon

Spawning gravels and suitable water temperatures for fall-run Chinook salmon occur throughout the lower reaches of the Middle and South Yuba rivers. If passage was provided at Englebright Dam, fall-run Chinook salmon likely would have access to these areas, although it is difficult to predict how far upstream fall-run Chinook salmon would migrate for spawning. Figure 3-16 illustrates the cumulative number of redds that could be supported in the identified spawning areas upstream of Englebright Lake in the Middle and South Yuba rivers.

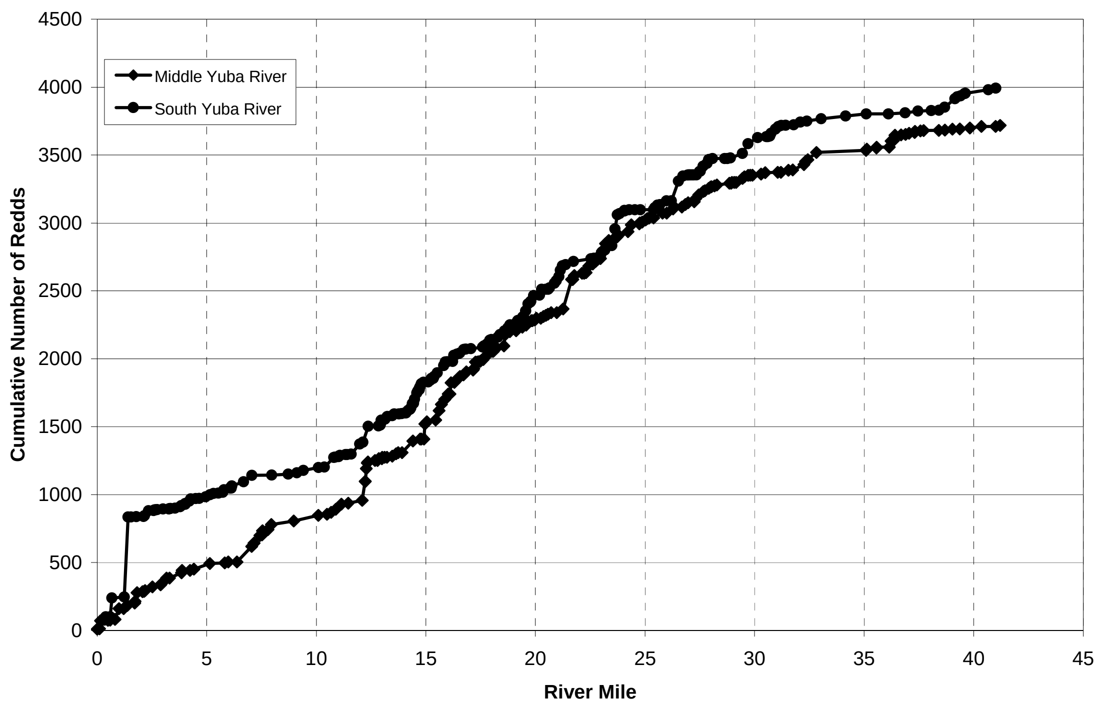

FIGURE 3-16
Cumulative Number of Chinook Salmon Redds Potentially Supported in the Middle and South Yuba Rivers
RM 0 indicates the confluence with the North Yuba River and Englebright Lake, respectively

3.3 Integration of Habitat Analyses for Other Life Stages

3.3.1 Adult Upstream Migration

The provision of unimpeded adult salmon and steelhead passage to the upper portion of the upper Yuba River watershed would be essential for introduction of these species in the watershed because the thermally suitable reaches for critical life stages (holding and rearing) would be located in the very upper reaches of the Middle Yuba River. If spring-run Chinook salmon could not migrate up to thermally suitable reaches for holding in pools prior to spawning, the adult fish could perish in downstream reaches because of stressful or lethal water temperatures. Additionally, if steelhead were only able to spawn in the lower reaches, their offspring likely could not tolerate the warm water conditions present during the summer months. The study team used aerial videography and field surveys to identify potential barriers for adult fish upstream migration. For the purpose of this analysis, it was assumed that passage would be provided at man-made barriers such as Our House Dam on the Middle Yuba River and at the natural low-flow barriers that exist in both rivers. Details of the passage analysis are included as Appendix C of this report.

The hydraulic factors that contribute to a fish migration barrier (stream flow combined with channel geometry) vary seasonally. The field surveys were conducted during seasonally low-flow conditions in the summer; therefore, the analysis examined historical daily flow records during the period when spring-run Chinook would migrate upstream (April to July). Because flows are naturally variable, conditions were categorized by hydrologic wet, above-normal, below-normal, dry, and critically dry water years. Based on the hydrologic analyses, fish passage at the low-flow barriers would not be impeded during wet and above-normal hydrologic conditions, but could be at least partially impeded during below-normal, dry, and critically dry conditions when average daily flows may be insufficient to ensure unimpeded fish passage. In some years, flows decline during the period of spring-run Chinook salmon migration and could block passage of later migrating fish to suitable habitats upstream of the barriers. However, even in drier years, there could be short periods of increased flows providing suitable migration conditions for Chinook salmon (due to rainfall events or water management).

Fish passage at the low-flow barriers could also be challenging for adult steelhead during the fall when flows are typically low. Although steelhead are stronger leapers than Chinook salmon, the fish would still have difficulty migrating past the barriers during low-flows during below-normal or drier hydrologic conditions. Steelhead migrating later during the winter would have a higher likelihood of successful passage when flows may be higher due to rainfall and increased runoff.

Through alteration of physical characteristics and/or altered hydrologic conditions, adequate passage for migrating adult spring-run Chinook salmon and steelhead could be provided at the natural barriers in most years. The physical alterations could include moving large boulders, modifying the localized channel gradient, and raising the elevation of plunge pools at the base of the obstruction. Physical alteration of the low-flow barriers to accommodate fish passage may be more feasible than flow augmentation. If anadromous salmonids are introduced to the upper Yuba River watershed, periodic maintenance of some sites may be necessary to ensure suitable fish passage conditions because the river channel may change periodically through bedload movement or rock slides, altering passage conditions. The habitat and water temperature analysis assumed that passage would be provided at man-made barriers such as Our House Dam and at the natural low-flow barriers. Passage options at these features would need to be considered in determining the overall feasibility of introduction of salmon and steelhead in the upper Yuba River watershed.

3.3.2 Adult Holding

Because naturally occurring stream flows are typically low and ambient air temperatures are high in Central Valley streams during the summer, spring-run Chinook salmon require thermal refugia (areas with cooler water) in which to hold prior to spawning. To support spring-run Chinook salmon in the Middle Yuba River, a thermally suitable reach containing a sufficient amount of holding habitat must be available. Attributes of Spring-run Chinook salmon holding habitat include deep pools, cover, proximity to spawning gravels, and cool water with adequate levels of dissolved oxygen. Cover may be provided by overhanging and submerged bedrock ledges, large submerged boulders, and bubble curtains (areas of turbulent, aerated water).

The study team used aerial videography followed by field verification of specific areas to identify suitable holding habitat in the Middle Yuba River (see Appendix C). Within the reach considered thermally suitable for spring-run Chinook salmon in the Middle Yuba River (see Figure 3-12), 15 pools were identified with habitat characteristics suitable for holding of adult spring-run Chinook salmon. Each holding pool would support at least 50 to 100 adult spring-run Chinook salmon, based on observations of adult spring-run Chinook salmon holding in Mill, Deer, and Butte creeks. Based on the size and configuration of the available pools, a minimum of 750 to 1,500 adult spring-run Chinook salmon could hold in this reach. Substantially higher numbers of adult spring-run Chinook salmon have been observed holding in pools in Butte Creek, so this estimate could be conservative. The analysis suggests that adequate holding habitat would exist within the thermally suitable reach on the Middle Yuba River for the predicted number of adult spring-run Chinook salmon that could potentially spawn within this reach (approximately 500 spawners). Holding habitat capacity for spring-run Chinook salmon was not predicted for the South Yuba River because no thermally suitable habitat was identified downstream of the passage barrier.

Some localized areas in the upper Yuba River watershed that were not identifiable through aerial videography or field verification could contain suitable holding habitat for spring-run Chinook salmon. These include pools not visible from the air and areas where physical characteristics would significantly change with increased stream flows. Even though many other pools are present in the Middle Yuba River, they were not considered suitable holding habitat because other necessary features were not present (e.g., shade, overhanging cover, and bubble curtain). Depending on site-specific conditions, stream flows higher than those observed during the surveys would be expected to improve habitat attributes such as water depth and bubble curtains in some pools, providing additional holding habitat.

If spring-run Chinook salmon were introduced to the upper Yuba watershed, the fish may hold in higher densities than assumed or use additional pools beyond those identified as having suitable characteristics in this assessment; therefore, the predicted holding capacity presented here should be considered conservative. The amount of holding habitat identified appears to be adequate to support the predicted number of adults that could spawn in the thermally suitable reach. Results of the holding habitat analysis suggest that holding habitat for spring-run Chinook salmon would not limit the number of spring-run Chinook salmon that could spawn in the upper Yuba River watershed under current operations.

3.3.3 Fry and Juvenile Rearing

The final step in evaluating habitat suitability for Chinook salmon and steelhead in the upper Yuba River watershed was determining whether the available rearing habitat could support the number of fry and juveniles that could be produced by the potential number of adults that could spawn in the thermally suitable reaches. This section describes the results of the evaluation for the fry life stage of Chinook salmon and steelhead (also referred to as young-of-year [YOY], or age 0+ fish), and the juvenile (age 1+ or older) steelhead life stage based on data collected during the initial phase of the studies program. Details of the field study on rearing habitat are included as Appendix E of this report.

The evaluation of potential fry and juvenile rearing capacity is especially important for steelhead, which typically rear in their natal stream for at least one summer and winter before outmigrating to the ocean. Because of their extended freshwater life history and the density-dependent population constraints often encountered by rearing steelhead, the production of steelhead smolts is frequently limited by the quality and quantity of rearing habitat (Stillwater Sciences, 2006). In contrast, Chinook salmon that adopt an ocean-type life history strategy (outmigrating as fry in their first winter or spring) are subject to fewer density-dependent effects that may limit population success during their short fresh water residence. Although spring-run Chinook salmon typically adopt a stream type life history strategy whereby they rear in fresh water for a year or more, high stream temperatures may cause Chinook salmon to abandon this strategy and outmigrate sooner (Nicholas and Hankin, 1989). Similar to what has been observed in Butte Creek (Ward et al., 2004a, b), Chinook salmon introduced into the upper Yuba River watershed may exhibit an ocean-type life history strategy due to the relatively high summer stream temperatures.

The number of Chinook salmon and steelhead that could rear over the summer in thermally suitable reaches of the Middle and South Yuba rivers was predicted by multiplying observed habitat-specific rearing densities (fish per unit area) for each species by the amount of habitat area available in these reaches. The rearing densities for spring-run Chinook salmon fry used in the analysis were derived from snorkel survey data collected in 1992 in Deer Creek, Lassen National Forest, California (USDA Forest Service, unpubl. data). Steelhead rearing densities used in the analysis were derived from rainbow trout snorkel survey data collected by T.R. Payne and Associates in the Middle and South Yuba rivers in summer 2004 (Appendix G). The amount of rearing habitat available for each species under current operations was estimated using data collected during the rearing habitat investigation (Appendix E). Predicted rearing capacities for each habitat type (e.g., pool, riffle, run) were summed to derive the total predicted rearing capacity for Chinook salmon and steelhead in each thermally suitable reach.

Spring-run Chinook Salmon

Under current operations, it was predicted that approximately 5.6 miles of thermally suitable habitat for spring-run Chinook salmon would be present in the Middle Yuba River downstream of the barrier at RM 34.4 (see Figure 3-12) if the fry outmigrate during the winter or spring and avoid high summer water temperatures. Spring-run Chinook salmon fry remaining to rear in the Middle Yuba River during summer would be restricted by high water temperatures to the 3.7 mile reach upstream of RM 30.7. However, because water temperatures in the Middle Yuba River would not be expected to exceed the 18.3°C critical rearing threshold at any location until late May or early June (see Figure 3-6), thermally suitable rearing habitat for spring-run Chinook salmon would be present throughout the river until this time. Chinook salmon fry that do not remain to rear in the upper reach where they hatched could still rear and outmigrate successfully if they left the river by the end of May.

Habitat-specific fry densities from Deer Creek, another Sacramento River tributary that supports spring-run Chinook salmon, were used to predict summer rearing capacity for spring-run Chinook salmon in the Middle Yuba River. Differences between the Deer Creek and Yuba River systems, combined with uncertainties associated with the estimates of habitat area make it difficult to accurately predict the rearing capacity for spring-run Chinook salmon fry in the Middle Yuba River. Therefore, the predicted rearing capacity was compared to the number of fry that could be produced by the predicted number of adult spawners to evaluate the potential for rearing habitat to limit spring-run Chinook salmon production in the upper Yuba River watershed.

Figure 3-17 graphically illustrates the predicted summer rearing capacity of spring-run Chinook salmon fry (age 0+) in thermally suitable reaches of the Middle Yuba River. Vertical lines indicate the minimum and maximum rearing capacity predicted using the minimum and maximum densities observed in Deer Creek and the marker indicates the predicted rearing capacity using the average density observed in Deer Creek. Within the approximately 3.7 miles of thermally suitable habitat for summer rearing of spring-run Chinook salmon in the Middle Yuba River under current operations, there is sufficient rearing habitat to support approximately 30,150 (range: 2,400 to 104,300) Chinook salmon fry. Rearing capacity for spring-run Chinook salmon was not predicted for the South Yuba River because no thermally suitable habitat was identified downstream of the passage barrier.

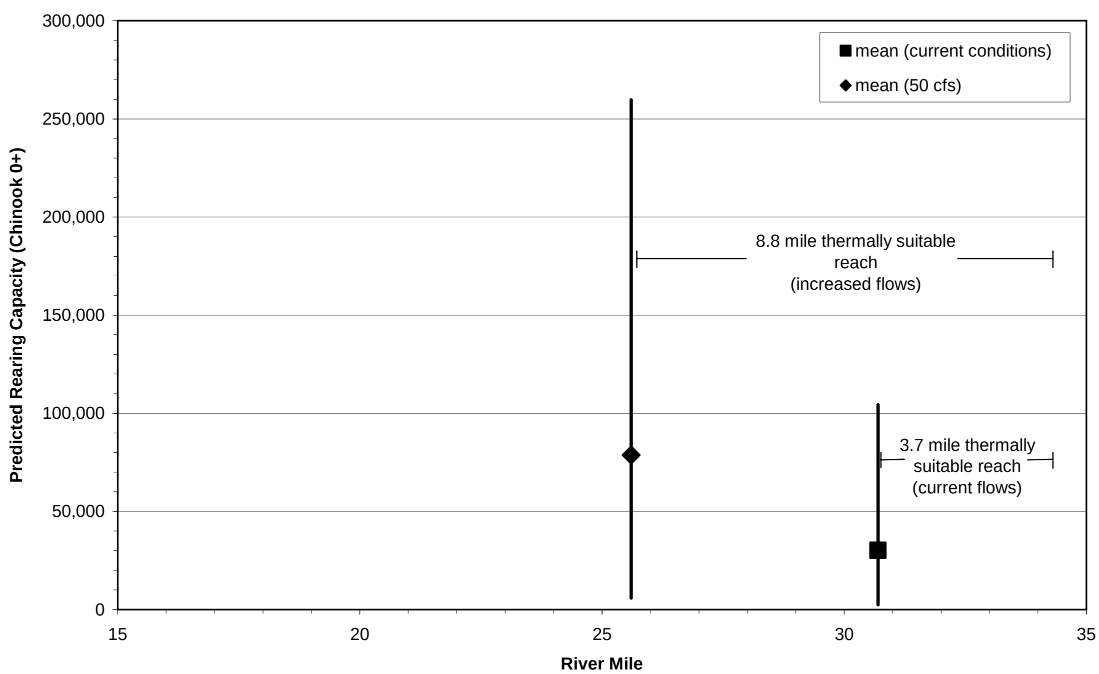

FIGURE 3-17
Predicted Summer Rearing Capacity of Spring-run Chinook Salmon Fry (age 0+) in Thermally Suitable Reaches of the Middle Yuba River Under Current and Increased Flows
Vertical lines indicate predicted minimum and maximum.

The predicted number of emergent fry that could be produced from the number of adults potentially spawning in this reach of the Middle Yuba River is approximately 570,000. This calculation assumes a fecundity of 5,000 eggs per female (Moyle, 2002) and a predicted survival-to-emergence of 76 percent (based on gravel permeability measurements[4] [Appendix D]). Comparison to the predicted number of juveniles that could rear over the summer in the identified thermally suitable reach under existing conditions (30,150) suggests that the number of emergent fry would far exceed the summer rearing capacity of the thermally suitable habitat in the Middle Yuba River. If many spring-run Chinook salmon fry adopted an ocean-type strategy and began migrating downstream shortly after emergence, leaving the Middle Yuba River before water temperatures become limiting in the downstream reaches, then rearing habitat would not be a factor limiting spring-run Chinook salmon production. Rearing habitat capacity could be a limiting factor on the number of spring-run Chinook salmon that could be supported in the Middle Yuba River if juvenile salmon remained in the river over the summer.

The predicted rearing capacity is based on the best available information, but may be conservative because:

- The GIS analysis and limited field verification used to derive estimates of available rearing habitat may have underestimated the amount of habitat
- Potential Chinook salmon rearing densities in the upper Yuba River watershed may be higher than the densities observed in Deer Creek and used in this analysis

Available information is insufficient to conclusively determine whether the available habitat in the thermally suitable reaches would support a sufficient number of fry or juveniles, which would ultimately return as adult spawners, to maintain a naturally self-sustaining population. However, because juvenile spring-run Chinook salmon could adopt an ocean-type strategy and leave the river before water temperatures become limiting, summer rearing habitat for spring-run Chinook salmon juveniles may not be a factor limiting production in the upper Yuba River watershed. A more sophisticated analysis using a population model incorporating time series analysis may be necessary to gain further resolution on whether the predicted number of adult spawners could be sustained over the long term.

Steelhead

It was predicted that suitable summer rearing temperatures for steelhead in the Middle Yuba River under current water operations would extend about 8.8 miles downstream of the natural barrier at RM 34.4 (see Figure 3-14). Although water temperatures during the remainder of the year (late September to May) are expected to remain below the suboptimal rearing temperature threshold of 20°C (see Figure 3-10), steelhead moving downstream to rear during this cooler time period would have to emigrate from the system before water temperatures again reached the critical threshold the following summer or return to upstream areas with cooler water to avoid being subjected to the stressful and potentially lethal effects of the high downstream temperatures. Due to the presence of low-flow migration barriers in downstream reaches of the Middle Yuba River (Appendix C) it was assumed that upstream movement by rearing steelhead would be minimal. Furthermore,

4 Measured permeability rates can be converted into an index of predicted survival rates from egg deposition to fry emergence (i.e., survival-to-emergence rates) using relationships derived from field observations of redds with differing permeabilities (Tagart 1976) and studies where the permeability of artificial redds was manipulated experimentally (McCuddin 1977).

because rearing steelhead are generally territorial and compete for space (Everest and Chapman, 1972), it is possible that rearing habitat in the thermally suitable reach upstream could be fully seeded by one or more age cohorts, allowing little or no opportunity for successful immigration from downstream areas.

Habitat-specific fry and age 1+ (based on size) densities observed in the Middle Yuba River during the rainbow trout snorkel surveys (Appendix G) were used to predict summer rearing capacity for steelhead in the Middle Yuba River. Potential differences between observed rainbow trout densities and potential steelhead rearing densities, combined with uncertainties associated with the estimates of habitat area make it difficult to accurately predict rearing capacities for steelhead in the Middle Yuba River. Therefore, the predicted rearing capacities were compared to the number of fry that could be produced by the predicted number of adult spawners to evaluate the potential for rearing habitat to limit steelhead production in the upper Yuba River watershed. Rearing capacity was not predicted for steelhead in the South Yuba River because no thermally suitable habitat was identified downstream of the natural upstream passage barrier at RM 35.4.

Figures 3-18 and 3-19 graphically illustrate the predicted summer rearing capacity of age 0+ and age 1+ steelhead that could rear over the summer in thermally suitable reaches of the Middle Yuba River. Within the approximately 8.8 miles of thermally suitable habitat for rearing steelhead in the Middle Yuba River under current operations, there would be sufficient rearing habitat to support approximately 9,000 (range: 900 to 34,500) age 0+ (YOY) steelhead (Figure 3-18). Due to their larger size and greater space requirements, fewer age 1+ and older steelhead could be supported in this reach. Predicted rearing capacity of age 1+ and older steelhead in the 8.8-mile thermally suitable reach of the Middle Yuba River is approximately 4,000 (range: 1,300 to 8,600) under current operations (Figure 3-19).

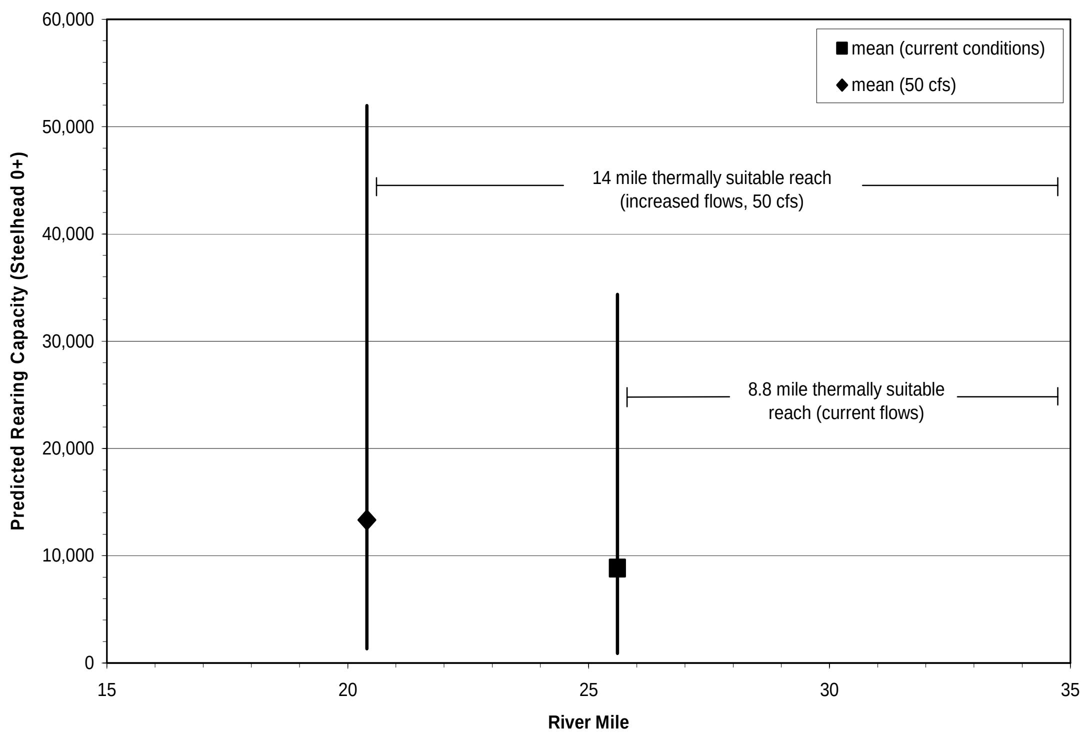

FIGURE 3-18
Predicted Summer Rearing Capacity of Age 0+ Steelhead in Thermally Suitable Reaches of the Middle Yuba River Under Current and Increased Flows
Vertical lines indicate predicted minimum and maximum.

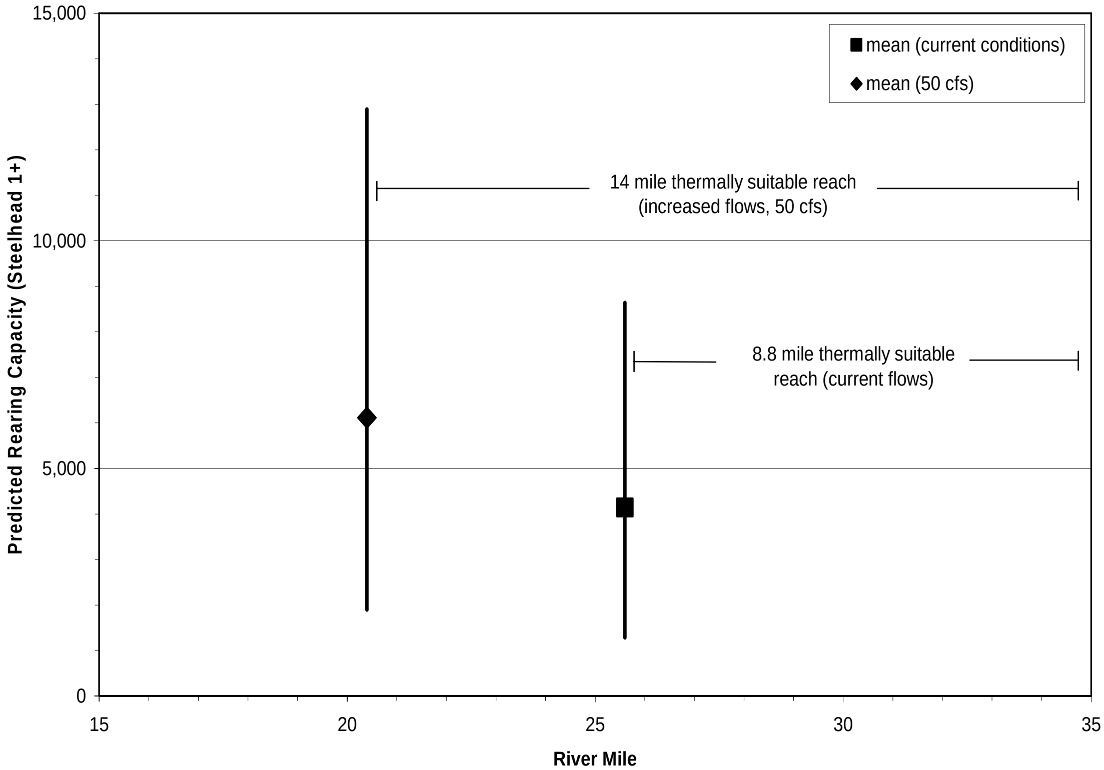

FIGURE 3-19
Predicted Summer Rearing Capacity of Age 1+ and Older Steelhead in Thermally Suitable Reaches of the Middle Yuba River Under Current and Increased Flows
Vertical lines indicate predicted minimum and maximum.

For comparative purposes, the predicted number of steelhead emergent fry that could be produced by the number of adults potentially spawning in this reach is approximately 973,000. This calculation assumes a fecundity of 4,000 eggs per female (McEwan and Jackson, 1996), and a predicted survival-to-emergence of 76 percent. Comparison to predicted rearing capacities suggests that the number of emergent steelhead fry could far exceed the potential summer rearing capacity of the available habitat in this reach for both fry (age 0+) and juveniles (age 1+ and older). This is not uncommon; the production of steelhead smolts is frequently limited by the quality and quantity of rearing habitat (Stillwater Sciences, 2006).

The predictions of rearing capacity are based on the best available information, but may be conservative because:

- The GIS analysis and limited field verification used to derive estimates of available rearing habitat may have underestimated the amount of habitat
- The snorkel surveys from which the rearing densities were derived were uncalibrated and, therefore, may have underestimated the true density of rearing rainbow trout in the Middle Yuba River
- Thermal refugia, acclimation effects, or other factors may enable steelhead to rear in areas downstream of the identified thermally suitable reach (rainbow trout have been observed in these downstream reaches)

Insufficient information exists to conclusively determine whether the available habitat in the thermally suitable reaches would support a sufficient number of fry and juvenile steelhead to maintain a naturally self-sustaining population. However, due to the conservative nature of the predictions and the uncertainties described above, results of the rearing habitat analysis suggest that summer rearing habitat would not limit production of adult steelhead in the upper Yuba River watershed. A more sophisticated analysis using a population model incorporating time series analysis may be necessary to gain further resolution on whether the predicted number of adult spawners could be sustained over the long term.

CHAPTER 4

Habitat Analysis: Increased Flows

The water temperature model was used as a preliminary screening tool to evaluate the effect of incremental flow increases on water temperatures during summer base flow conditions. The water temperature model described in Appendix A was used to predict the effect of increased releases from Jackson Meadows Reservoir through Milton Reservoir on water temperatures in the Middle Yuba River, and the effect of increased releases from Lake Spaulding on water temperatures in the South Yuba River. No change in water temperature at the release point was modeled. This analysis was conducted to assess the sensitivity of water temperature to stream flow and to evaluate whether increased flows could provide additional thermally suitable habitat for spring-run Chinook salmon and steelhead in the Upper Yuba River watershed. The range of increased flows was chosen based on the reasonable limits of the water temperature model, and was not intended to be used as recommendations for minimum flow requirements.

Output from the water temperature model was used to identify river reaches that would have suitable water temperatures at the highest modeled flow (50 cfs). While intermediate flows (i.e., 10, 20, 30, and 40 cfs) were modeled, only results from model runs with the highest flow (50 cfs) are reported here. The downstream extent of thermally suitable reaches with intermediate flows would be between those identified under current operations and those identified here for release flows of 50 cfs. Only reaches available to spring-run Chinook salmon and steelhead (i.e., below the first total barrier to upstream migration) were assessed for thermal suitability. The following section presents the results of the analysis and identifies the thermally suitable reaches available for each life stage of spring-run Chinook salmon and steelhead, and the predicted number of spring-run Chinook salmon and steelhead that could be supported in the thermally suitable habitat.

4.1 Thermally Suitable Reaches

4.1.1 Spring-run Chinook Salmon

Because water temperatures are naturally cool during the upstream migration period and were not considered limiting under current water operations, thermally suitable habitat was evaluated only for the adult holding, spawning and incubation, and juvenile rearing life stages of spring-run Chinook salmon with increased flows.

Adult Holding

Figure 4-1 illustrates the reaches where water temperatures were predicted to remain suitable for holding adult spring-run Chinook salmon in the upper Yuba River watershed. On the Middle Yuba River, water temperatures were predicted to remain below the suboptimal threshold for adult holding (19°C) in areas above approximately RM 22.7 (between Wolf Creek and Kanaka Creek) with increased flow (50 cfs). This represents an increase of approximately 6 miles of thermally suitable habitat compared to current water operations. On the South Yuba River, water temperatures were predicted to remain below the suboptimal threshold in an approximately 1-mile long reach below the barrier to upstream migration.

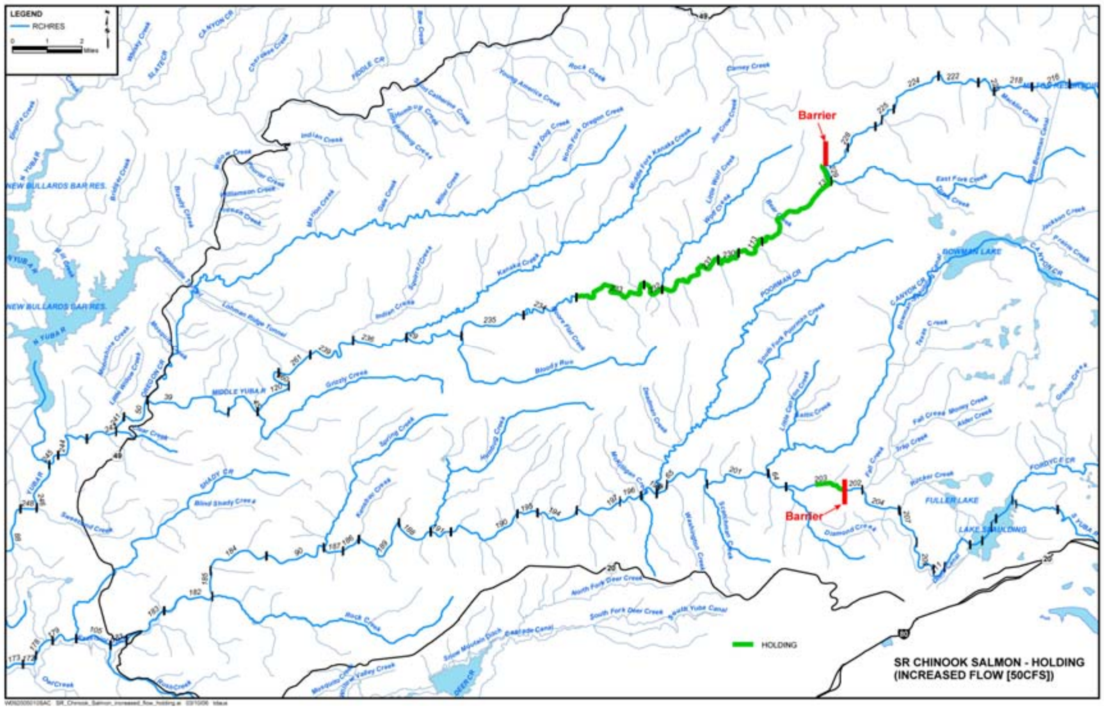

FIGURE 4-1
River Reaches with Suitable Water Temperatures for Adult Spring-run Chinook Salmon Holding (in green)
in the Middle and South Yuba Rivers Predicted with Increased Flows (50 cfs)
Hatch marks indicate the reaches used in the water temperature model.

Spawning and Egg Incubation

As shown in Figure 4-2, water temperatures suitable for spawning and incubation of spring-run Chinook salmon were predicted upstream of approximately RM 28.8 (upstream of Wolf Creek) during September on the Middle Yuba River and downstream later in the spawning and incubation period. The 5.6-mile reach identified as having suitable water temperatures before September 1 represents an increase of approximately 5 miles of available habitat with suitable water temperatures compared to current water operations. Suitable temperatures for spawning and incubation on the South Yuba River were predicted only a short distance downstream of Langs Crossing until later in the spawning and incubation period. On the South Yuba River, the first total barrier to upstream passage is located downstream of reaches predicted to have suitable water temperatures for spawning and incubation in September; therefore, no thermally suitable habitat would be available for spawning or incubation of spring-run Chinook salmon until later in the year. By October 1, water temperatures were predicted to be suitable throughout the South Yuba River, at least as far downstream as Missouri Bar (RM 24) (see Figure 4-2).

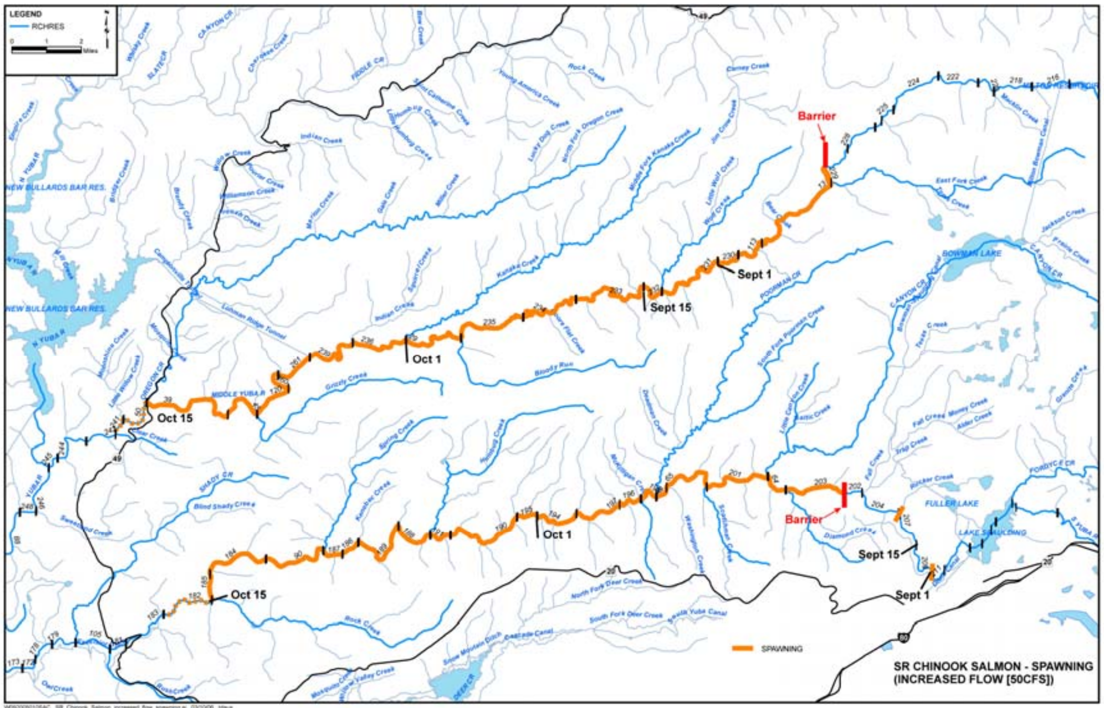

FIGURE 4-2
River Reaches With Suitable Water Temperatures for Spring-run Chinook Salmon Spawning and Incubation (in orange) in the Middle and South Yuba Rivers Predicted With Increased Flows (50 cfs)

Rearing and Outmigration

With increased flow (50 cfs) on the Middle Yuba River, summer water temperatures were predicted to remain below the threshold considered suitable for rearing (18.3°C) upstream of approximately RM 25.6 (about 1 mile downstream of Wolf Creek) (Figure 4-3). This represents an increase of approximately 5 miles of thermally suitable habitat compared to current water operations. On the South Yuba River, suitable temperatures for rearing were predicted only a short distance downstream of Langs Crossing. The first total barrier to upstream migration is located near the downstream end of the reach with suitable water temperatures for rearing during the summer; therefore, no thermally suitable habitat would be available for summer rearing of spring-run Chinook salmon (see Figure 4-3). Based on observed emigration patterns for juvenile spring-run Chinook salmon inhabiting a warmer Sacramento River tributary (Butte Creek), juvenile spring-run Chinook salmon may outmigrate as fry before temperatures become unsuitable (Ward and McReynolds, 2001; Ward et al., 2004a, b).

4.1.2 Steelhead

Because steelhead would likely migrate through the Middle and South Yuba rivers primarily during the fall and winter when water temperatures are typically low, only the spawning and incubation, and juvenile rearing life stages were evaluated under conditions of increased flows.

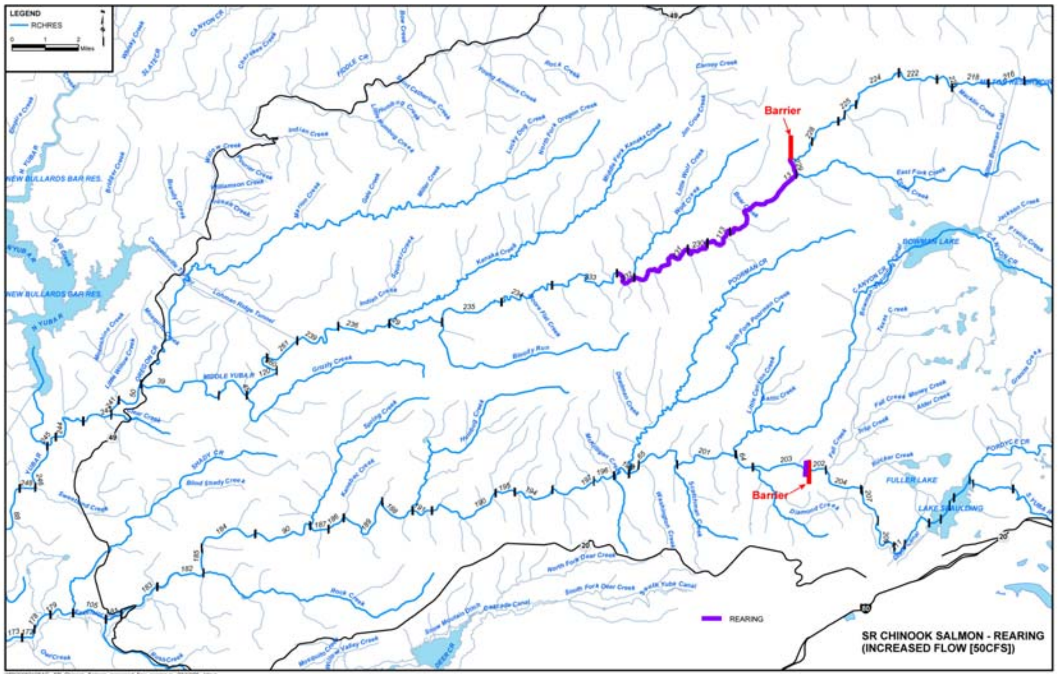

FIGURE 4-3
River Reaches with Suitable Water Temperatures for Spring-run Chinook Salmon Summer Rearing (in purple) in the Middle and South Yuba Rivers Predicted with Increased Flows (50 cfs)

Spawning and Egg Incubation

Suitable temperatures for spawning and egg incubation (less than 12.8°C) were predicted in all reaches of the Middle Yuba River during the early portion of the spawning and incubation period. River reaches upstream of approximately RM 20.4 (between Kanaka and Wolf creeks) would have suitable temperatures for spawning during the entire spawning and incubation period with increased flow (50 cfs). Figure 4-4 indicates the predicted downstream extent of suitable water temperatures for spawning and incubation of steelhead with increased flow. Dates indicate that suitable water temperatures were predicted on or before the indicated date at that location. Before June, water temperatures suitable for incubation would be found at least as far downstream as Kanaka Creek on the Middle Yuba River. Before this date, suitable incubation temperatures were predicted several miles downstream of this point. Compared to current water operations, increased flow was predicted to result in an increase of approximately 2.3 miles of thermally suitable habitat for steelhead spawning and incubation in the Middle Yuba River.

On the South Yuba River, suitable temperatures for spawning and incubation were predicted only a short distance downstream of Langs Crossing except early in the incubation period. The first total barrier to upstream fish passage is located downstream of reaches where water temperatures would be suitable for incubation prior to June; therefore, no habitat with suitable water temperatures would be available for spawning or incubation of steelhead, except perhaps for fish that spawn early in the year (see Figure 4-4). During May, water temperatures suitable for incubation were predicted as far downstream as Missouri Bar on the South Yuba River.

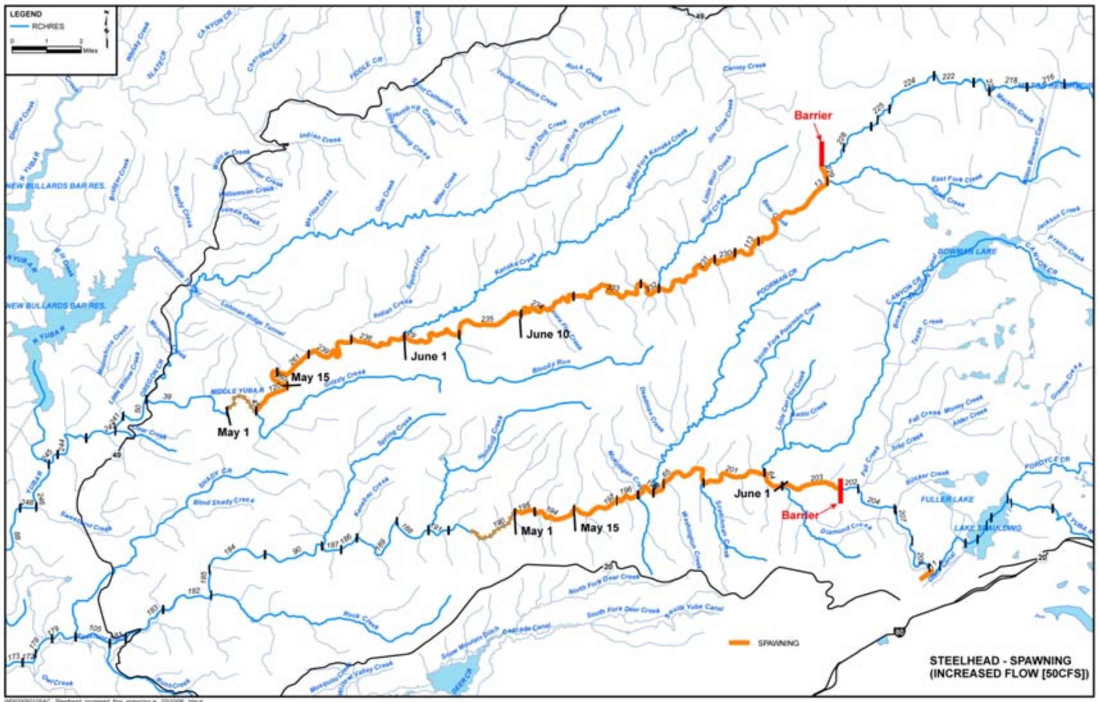

FIGURE 4-4
River Reaches with Suitable Water Temperatures for Steelhead Spawning and Incubation in the Middle and South Yuba Rivers[5] Predicted With Increased Flows (50 cfs).

Rearing and Outmigration

With increased flow (50 cfs) in the Middle Yuba River, water temperatures were predicted to remain below the threshold for rearing (20.0°C) during the summer in all reaches of the Middle Yuba River upstream of approximately RM 20.4 (between Kanaka and Wolf creeks) (Figure 4-5). Compared to the reach with suitable water temperatures under current water operations, this represents an increase of approximately 5 miles of thermally suitable habitat. With increased flows on the South Yuba River, water temperatures were predicted to remain below the threshold for rearing (20.0°C) during the summer as far downstream as RM 32.9, approximately 2.5 miles downstream of the first total barrier to upstream migration (see Figure 4-5). Juvenile steelhead rearing below RM 20.4 on the Middle Yuba River and below RM 32.9 on the South Yuba River would be subjected to high water temperatures during the summer and would likely experience chronic or acute effects, including mortality.

[5] As noted in the text, the natural barrier on the South Yuba River is downstream of reaches predicted to have suitable water temperatures and would block access to these reaches.

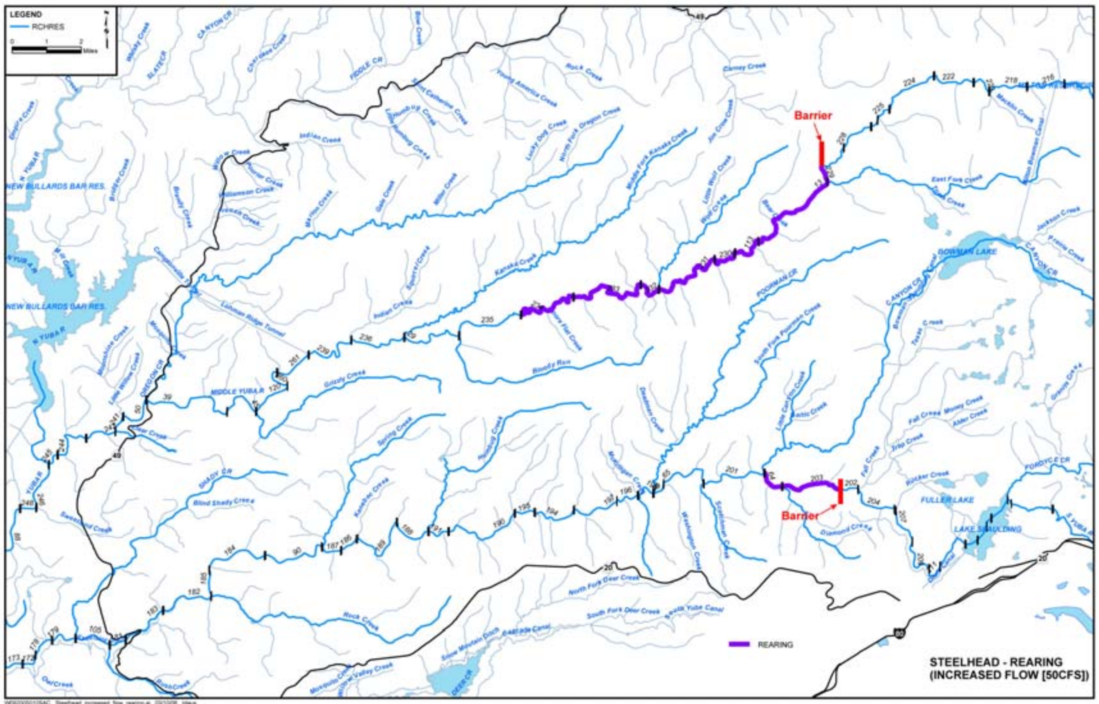

FIGURE 4-5
River Reaches with Suitable Water Temperatures for Steelhead Summer Rearing (in purple)
in the Middle and South Yuba Rivers Predicted With Increased Flows (50 cfs)

4.1.3 Fall-run Chinook Salmon

If passage beyond Englebright Dam were provided, increased flow in the Middle and South Yuba rivers would not be expected to provide any additional benefit to fall-run Chinook salmon in terms of spawning habitat quality or quantity because both suitably-sized spawning gravels and suitable water temperatures would be available to fall-run Chinook salmon throughout the Middle and South Yuba rivers at the appropriate time, even under current operations (see Chapter 3). In order to avoid unsuitable summer rearing temperatures, juvenile fall-run Chinook salmon using the upper Yuba River watershed would need to exhibit the ocean-type life history (which is a strategy typical of fall-run) and leave the lower reaches of the rivers before temperatures become unsuitable for summer rearing.

4.2 Number of Chinook Salmon and Steelhead Redds

As described in Chapter 3 for current operations, the approach to determining the number of Chinook salmon and steelhead redds that could potentially be supported in the upper Yuba River watershed with increased flow included identifying the reaches with both suitable habitat and suitable water temperatures that would be accessible to these species. Suitable reaches were identified as those reaches downstream of the first total barrier to upstream migration (see Appendix C) that would have suitable water temperatures for completion of each species' life cycle. Increased flow was predicted to extend the linear extent of thermally suitable habitat within each river for each species, and increase the predicted number of fish that could be supported in the available habitat. No attempt was made to quantify the potential increase in available habitat that may occur with increased flow due to increased depths or inundation of previously dry areas. An analysis of this type would require much more rigorous field examination and hydraulic modeling than was conducted for the feasibility-level analysis for the UYRSP.

4.2.1 Spring-run Chinook Salmon

Figure 4-6 shows the linear extent of thermally suitable habitat predicted for spring-run Chinook salmon below the first natural barrier to upstream fish passage on the Middle and South Yuba rivers. The results of the analysis, based on temperature and hydrologic conditions in 2004, suggest that thermally suitable habitat for spring-run Chinook salmon, would extend approximately 11.7 miles downstream of the barrier (RM 34.4) to RM 22.7 on the Middle Yuba River under conditions of increased flow (50 cfs). As in the analysis for current operations (Chapter 3), it was assumed that adult spring-run Chinook salmon would continue to hold in this area until water temperatures become suitable for spawning, and most rearing spring-run Chinook salmon fry would leave the river before summer water temperatures exceed their temperature tolerance. On the South Yuba River, it was predicted that less than 1 mile of thermally suitable habitat would be available for spring-run Chinook salmon because of high summer water temperatures (see Figure 4-6). Without changing the release temperature, increased flow (50 cfs) was predicted to result in an additional 6 miles (Middle Yuba River) and 1 mile (South Yuba River) of thermally suitable habitat compared to current water operations.

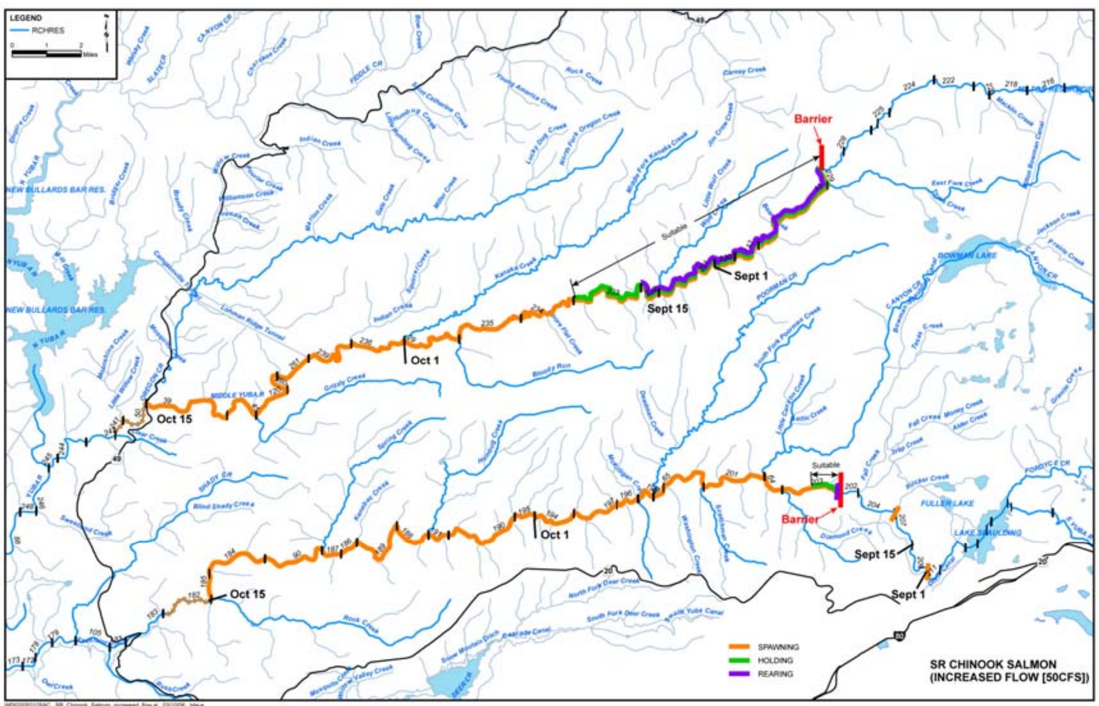

FIGURE 4-6
River Reaches with Suitable Water Temperatures for Spring-run Chinook Salmon in the Middle and South Yuba Rivers Predicted with Increased Flows (50 cfs)

Figure 4-7 shows the linear extent of thermally suitable habitat and cumulative number of spring-run Chinook salmon redds potentially supported below the barrier to upstream fish passage on the Middle Yuba River. Figure 4-8 shows the linear extent of thermally suitable habitat and cumulative number of spring-run Chinook salmon redds potentially supported below the barrier to upstream fish passage on the South Yuba River. Based on the analysis of spawning habitat (Appendix D), approximately 820 spring-run Chinook salmon redds could be supported in the reach predicted to be suitable in the Middle Yuba River with increased flow. Approximately 20 spring-run Chinook salmon redds could be supported in the reach with suitable water temperatures on the South Yuba River. Increased flow (50 cfs) was predicted to result in an additional 580 redds (Middle Yuba River) and 20 redds (South Yuba River) possible in the thermally suitable habitat compared to the number of redds possible under current water operations.

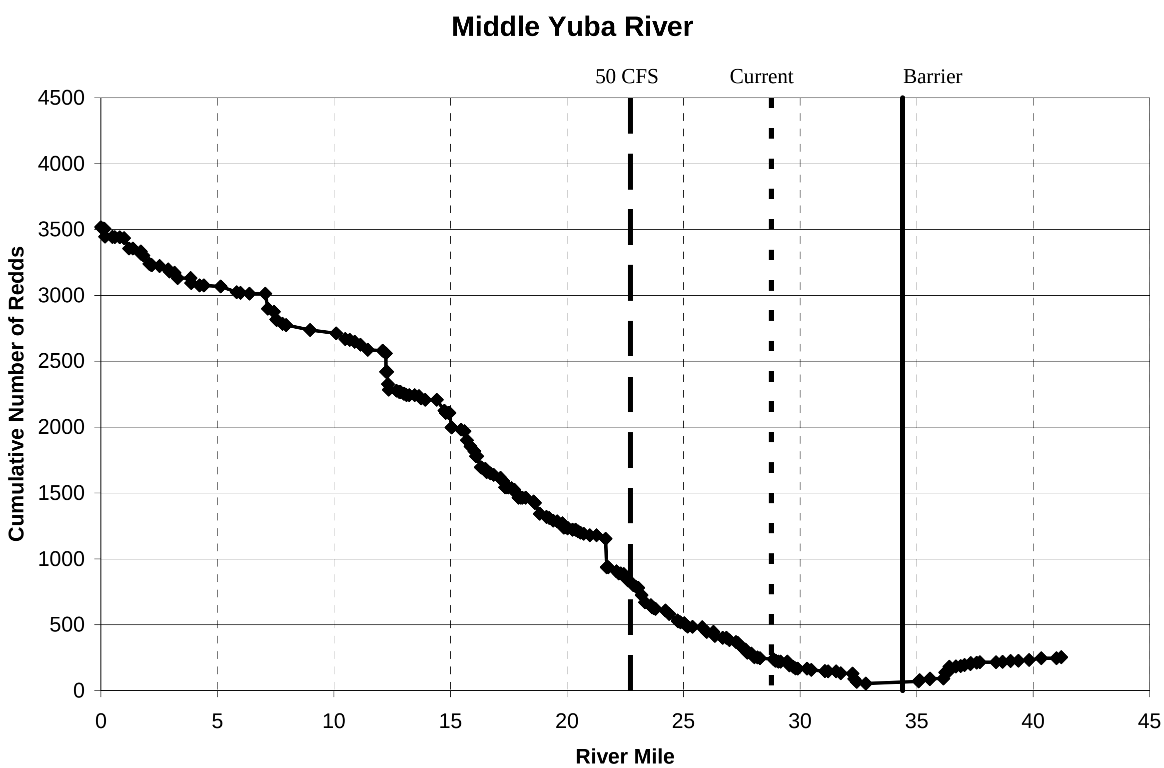

FIGURE 4-7
Downstream Extent of Thermally Suitable Habitat and Cumulative Number of Spring-run Chinook Salmon Redds Potentially Supported Below the First Total Barrier (RM 34.4) in the Middle Yuba River Predicted With Increased Flow (50 cfs)

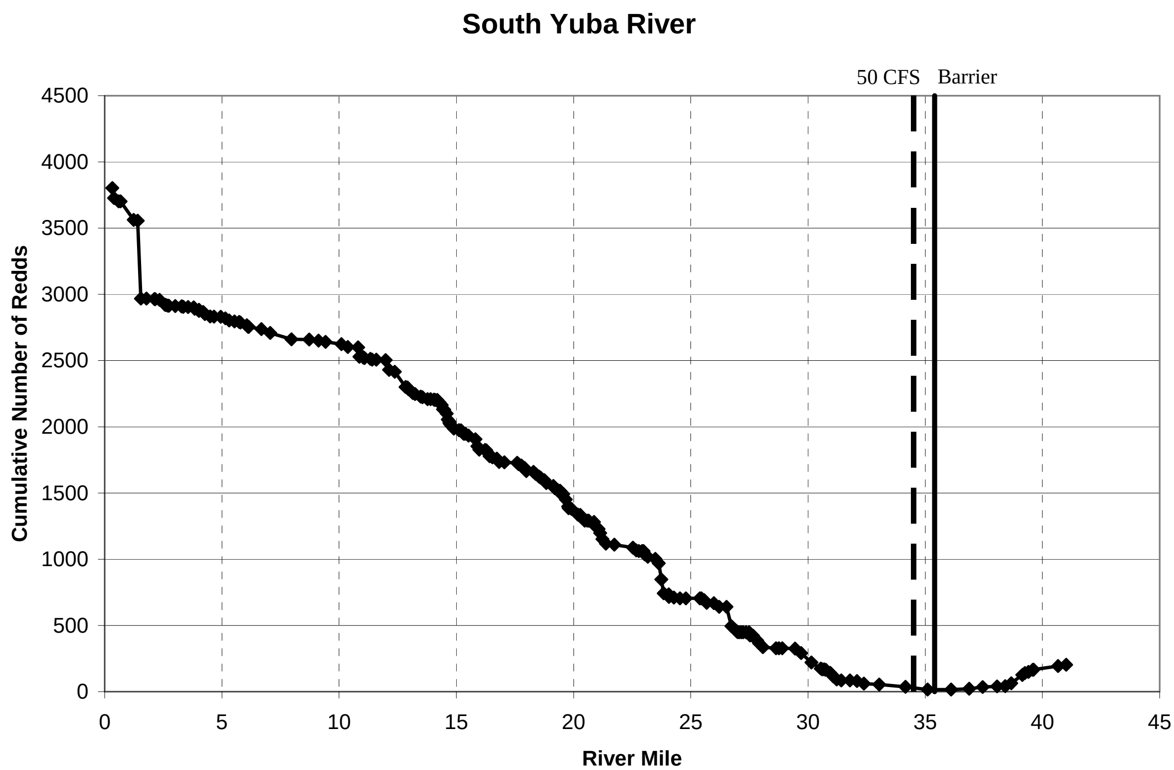

FIGURE 4-8
Downstream Extent of Thermally Suitable Habitat and Cumulative Number of Spring-run Chinook Salmon Redds Potentially Supported Below the First Total Barrier (RM 35.4) in the South Yuba River Predicted with Increased Flow (50 cfs)

Assuming one female Chinook salmon per redd and a sex ratio of 1:1, it was predicted that up to 1,640 spring-run Chinook salmon spawners could be supported by the available spawning habitat in the thermally suitable reach of the Middle Yuba River; up to 40 spring-run Chinook salmon could be supported in the South Yuba River with increased flows of 50 cfs.

4.2.2 Steelhead

In the upper Yuba River watershed, the juvenile rearing life stage was considered the most limiting for steelhead (see Chapter 3). Figure 4-9 shows the linear extent of thermally suitable habitat the Middle and South Yuba rivers predicted with increased flows. The results of the analysis, based on temperature and hydrologic conditions in 2004, suggest that thermally suitable habitat for steelhead in the Middle Yuba River would extend approximately 14 miles downstream of the natural barrier to upstream migration at RM 34.4 to approximately RM 20.4 (between Wolf Creek and Kanaka Creek). This represents an increase of approximately 5.2 miles of thermally suitable habitat compared to current water operations. Based on the analysis of spawning habitat (Appendix D), it was predicted that up to 1,320 steelhead redds could be supported in the Middle Yuba River with increased flow, an increase of approximately 1,000 redds compared to current water operations (Figure 4-10). On the South Yuba River, the analysis suggests that approximately 2.5 miles of thermally suitable habitat would be available for steelhead with increased flows of 50 cfs (see Figure 4-9); approximately 50 steelhead redds could be supported in this reach (Figure 4-11).

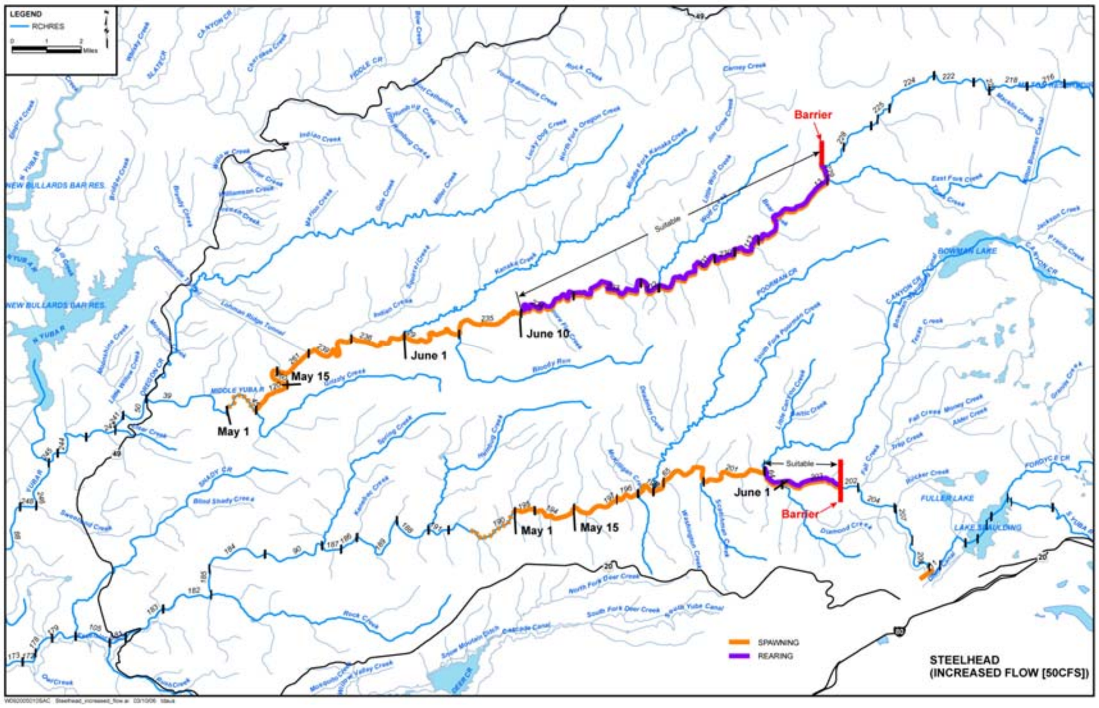

FIGURE 4-9
River Reaches With Suitable Water Temperatures for Steelhead in the Middle and South Yuba Rivers Predicted with Increased Flows (50 cfs)

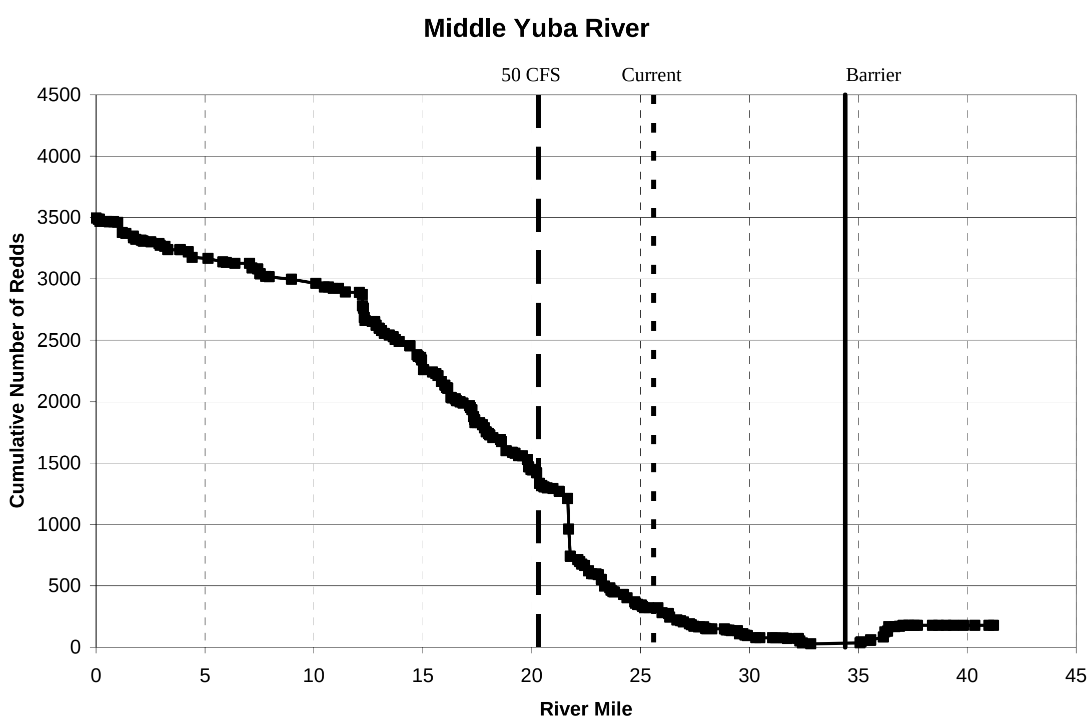

FIGURE 4-10
Downstream Extent of Thermally Suitable Habitat and Cumulative Number of Steelhead Redds Potentially Supported Below the First Total Barrier (RM 34.4) in the Middle Yuba River Predicted With Increased Flow (50 cfs)

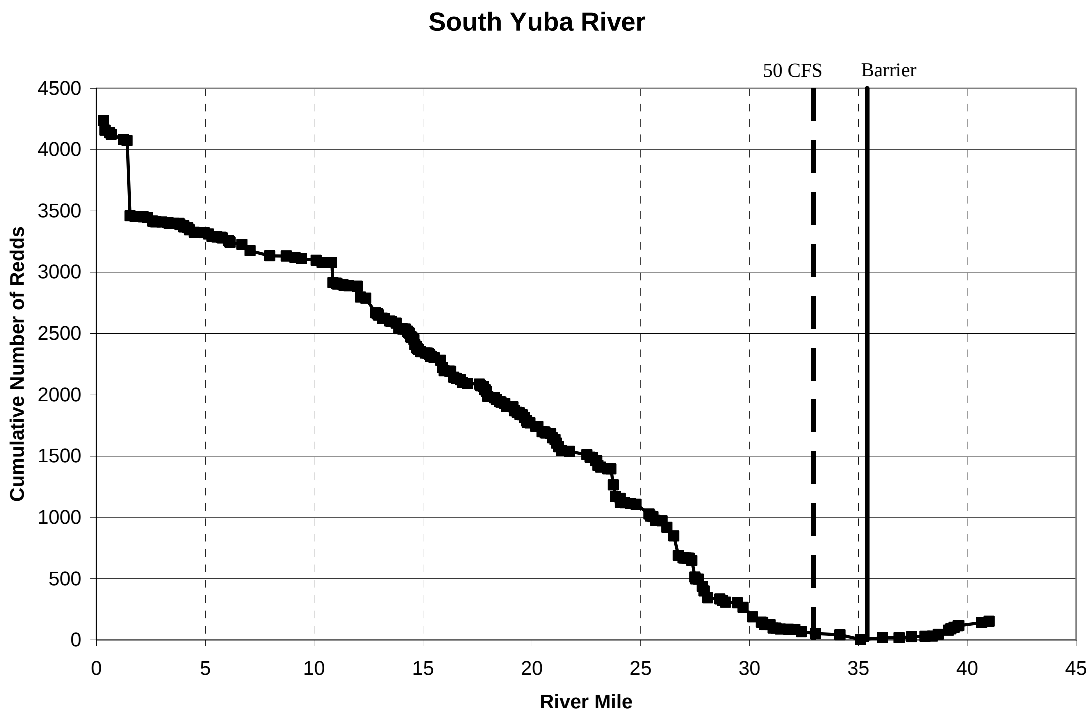

FIGURE 4-11
Downstream Extent of Thermally Suitable Habitat and Cumulative Number of Steelhead Redds Potentially Supported Below the First Total Barrier (RM 35.4) in the South Yuba River Predicted With Increased Flow (50 cfs).

Assuming one female steelhead per redd and a sex ratio of 1:1, it was predicted that approximately 2,640 steelhead spawners could be supported in the Middle Yuba River and up to 100 steelhead could be supported in the South Yuba River with increased flows of 50 cfs.

4.2.3 Fall-run Chinook Salmon

Increased flow in the Middle and South Yuba rivers would not provide any additional benefit to fall-run Chinook salmon because both suitably-sized spawning gravels and suitable water temperatures would be available to fall-run Chinook salmon throughout the Middle and South Yuba rivers at the appropriate time under current operations (see Chapter 3). Thus, no additional production of fall-run Chinook salmon would be expected at the higher flows.

4.3 Integration of Habitat Analyses for Other Life Stages

4.3.1 Adult Upstream Migration

Increased flows of 50 cfs during the upstream migration period of spring-run Chinook salmon might improve conditions for fish passage at low-flow barriers in the upper Yuba River watershed. The potential benefits would depend on hydrologic and site-specific conditions at each barrier. The increased flow might not assure fish passage during below-normal, dry, and critically dry annual hydrologic conditions. As discussed in Chapter 3 for current operations, the low-flow barriers could be physically altered to ensure fish passage regardless of hydrologic conditions. The physical alterations could include moving large boulders, modifying the localized channel gradient, and raising the elevation of plunge pools at the base of the obstruction. Physical alteration of the low-flow barriers to accommodate fish passage may be more feasible than flow augmentation. Fish passage at the high flow barriers could only be accomplished by physical alteration or the provision of fish passage facilities. The habitat and water temperature analysis assumed that passage would be provided at man-made barriers such as Our House Dam and at the natural low-flow barriers. Passage options at these features would need to be considered in determining the overall feasibility of introduction of salmon and steelhead in the upper Yuba River watershed.

4.3.2 Adult Holding

Because increased flows would extend the thermally suitable reach for holding adult spring-run Chinook salmon by over 6 miles, there would be more pools available for holding spring-run Chinook salmon. Based on surveys performed by the study team, approximately 18 additional pools suitable for holding spring-run Chinook salmon would be provided in the expanded reach. Each holding pool would support at least 50 to 100 adult spring-run Chinook salmon, based on observations of adult spring-run Chinook salmon holding in Mill, Deer, and Butte creeks. Based on the size and configuration of the available pools, the additional pool habitat was predicted to support at least 900 to 1,800 more adult spring-run Chinook salmon than under current operations for a total of 1,650 to 3,300 adult salmon.

Additionally, the increased flow would likely enhance the quality of holding pools due to improved habitat attributes such as greater bubble curtains for cover, increased oxygenation, and increased depths. The amount of holding habitat appears to be adequate to support the predicted number of adults that could spawn in the thermally suitable reach (approximately 1,600) on the Middle Yuba River with increased flows. Results of holding habitat analysis suggest that holding habitat for spring-run Chinook salmon would not limit the number of spring-run Chinook salmon that could spawn in the upper Yuba River watershed with increased flows.

4.3.3 Fry and Juvenile Rearing

Predicted rearing capacity with increased flow was based on the increase in the length of the reach with suitable water temperatures. No attempt was made to quantify the potential increase in rearing habitat that could occur with increased flow due to increased depths or inundation of previously dry areas (i.e., lateral expansion of the wetted channel). An analysis of this type would require a much more rigorous evaluation, including field studies and hydraulic modeling, than was possible for the feasibility-level scope of the UYRSP.

Spring-run Chinook Salmon

With increased flows of 50 cfs, approximately 11.7 miles of thermally suitable habitat for spring-run Chinook salmon would be present in the Middle Yuba River downstream of the barrier at RM 34.4 (see Figure 4-6) if the fry outmigrate during the winter or spring and avoid high summer water temperatures. Spring-run Chinook salmon fry remaining to rear in the Middle Yuba River during the summer would be restricted by high water temperatures to an 8.8-mile reach upstream of RM 25.6. However, because water temperatures in the Middle Yuba River likely would not exceed the 18.3°C critical rearing threshold at any location until late May or early June, thermally suitable rearing habitat for spring-run Chinook salmon would be present throughout the river until this time. Chinook salmon fry that do not remain to rear in the upper reach where they hatched could still rear and outmigrate successfully if they left the river by the end of May.

As described in Chapter 3 for current operations, habitat-specific fry densities from Deer Creek, another Sacramento River tributary that supports spring-run Chinook salmon, were used to predict summer rearing capacity for spring-run Chinook salmon in the Middle Yuba River. Differences between the Deer Creek and Yuba River systems, combined with uncertainties associated with the estimates of habitat area, make it difficult to accurately predict the rearing capacity for spring-run Chinook salmon fry in the Middle Yuba River. Therefore, the predicted rearing capacity was compared to the number of fry that could be produced by the predicted spawning population to evaluate the potential for rearing habitat to limit spring-run Chinook salmon production in the upper Yuba River watershed with increased flows.

Figure 3-17 graphically illustrates the predicted summer rearing capacity of spring-run Chinook salmon fry (age 0+) in thermally suitable reaches of the Middle Yuba River under current operations and with increased flows. Within the approximately 8.8 miles of habitat predicted to be thermally suitable for summer rearing of spring-run Chinook salmon in the Middle Yuba River with increased flows, there would be sufficient rearing habitat to support approximately 78,700 (range: 5,800 to 260,000) Chinook salmon fry. This represents an increase in Chinook salmon fry rearing capacity of approximately 120 percent over current operations in the Middle Yuba River. Rearing capacity for spring-run Chinook salmon was not predicted for the South Yuba River because little thermally suitable habitat was identified downstream of the passage barrier.

Using the same assumptions regarding fecundity and survival described for current operations, the predicted number of emergent fry that could be produced by the number of adults potentially spawning in this 8.8-mile thermally suitable reach of the Middle Yuba River would be approximately 1.8 million. Comparison to the predicted number of juveniles that could rear over the summer in the identified thermally suitable reach with increased flow (78,700) suggests that the number of emergent fry could far exceed the summer rearing capacity of the available habitat in the Middle Yuba. If many spring-run Chinook salmon fry adopted an ocean-type strategy and began migrating downstream shortly after emergence, leaving the Middle Yuba River before water temperatures become limiting in the downstream reaches, then rearing habitat would not be a factor limiting spring-run Chinook salmon production. Rearing habitat capacity could be a limiting factor on the number of spring-run Chinook salmon that could be supported in the Middle Yuba River if juvenile salmon remained in the river over the summer.

As previously described, available information is insufficient to conclusively determine whether the available habitat in the thermally suitable reaches would support a sufficient number of fry or juveniles that would ultimately return as adult spawners. However, because juvenile spring-run Chinook salmon could adopt an ocean-type strategy and leave the river before water temperatures become limiting, summer rearing habitat for spring-run Chinook salmon juveniles may not be a factor limiting production in the upper Yuba River watershed.

Steelhead

Habitat-specific fry and age 1+ (based on size) densities observed in the Middle Yuba River during the rainbow trout snorkel surveys (Appendix G) were used to predict summer rearing capacity for steelhead in the Middle Yuba River. Potential differences between observed rainbow trout densities and potential steelhead rearing densities, combined with uncertainties associated with the estimates of habitat area, make it difficult to accurately predict rearing capacities for steelhead in the Middle Yuba River. Therefore, the predicted rearing capacities were compared to the number of fry that could be produced by the predicted spawning population to evaluate the potential for rearing habitat to limit steelhead production in the upper Yuba River watershed. Rearing capacity was not predicted for steelhead in the South Yuba River because little thermally suitable habitat was identified downstream of the natural upstream passage barrier at RM 35.4.

Figures 3-18 and 3-19 graphically illustrate the predicted summer rearing capacity of age 0+ and age 1+ steelhead in thermally suitable reaches of the Middle Yuba River under current operations and with increased flows of 50 cfs. Vertical lines indicate the minimum and maximum rearing capacity predicted using the minimum and maximum densities observed in the Middle Yuba River. The marker indicates the predicted rearing capacity using the average rainbow trout density observed in the Middle Yuba River. Within the approximately 14 miles of thermally suitable habitat for rearing steelhead in the Middle Yuba River with increased flows of 50 cfs, there would be sufficient rearing habitat to support approximately 13,000 (range: 1,300 to 52,000) age 0+ steelhead (Figure 3-18). Due to their larger size and greater space requirements, fewer age 1+ and older steelhead could be supported in this reach. Predicted rearing capacity of age 1+ and older steelhead in the 14-mile thermally suitable reach of the Middle Yuba River is approximately 6,000 (range: 1,900 to 13,000) (Figure 3-19).

With increased flows in the Middle Yuba River, gains in potential spawning habitat would be proportionally larger than the potential gains in rearing habitat, leading to production of an even greater number of emergent fry. Using the same assumptions regarding fecundity and survival described previously for current operations, it was predicted that approximately 4 million emergent fry could be produced by the 2,640 adult steelhead potentially supported in the thermally suitable reach. Therefore, the number of emergent steelhead fry could far exceed the potential rearing capacity of the available habitat in this reach for both fry (age 0+) and juveniles (age 1+ and older) steelhead.

Insufficient information exists to conclusively determine whether the available habitat in the thermally suitable reaches with increased flows would support a sufficient number of fry and juvenile steelhead to maintain a naturally self-sustaining population. However, due to the conservative nature of the predictions and because rearing habitat capacity would be increased relative to current operations, results of the rearing habitat analysis suggest that summer rearing habitat would not limit production of adult steelhead in the upper Yuba River watershed.

CHAPTER 5

Additional Considerations

5.1 Water Temperature Modeling

5.1.1 Variation in Meteorological Conditions

The analysis of available habitat under current operations and with increased flows described previously relied primarily on water temperature data for one year (2004). The water temperature model was calibrated using 2004 data (see Appendix A). Because stream temperatures could be influenced by higher air temperatures, especially if they occurred in a year of low summer flows, basing the analysis on data from a single year may not account for the full range of variability likely to be seen in the future. To examine the potential influence of using a single year in the analysis, air temperatures for other years were reviewed. Based on that review, 2004 was not considered an extreme year in terms of summer air temperatures, but it was one of the warmer years on record, ranking 19th and 17th out of a 52-year period of record in July and August, respectively (see Appendix A). Meteorological (met) data from 2003 indicate that summer air temperatures were warmer than in 2004. Observed water temperatures in 2003 were not appreciably different than in 2004 or 2005 at most monitoring locations (see Appendix F). However, this could be due to the higher summer flows observed in 2003, particularly in the South Yuba River. Observed water temperatures in the Middle Yuba River below Wolf Creek are shown in Figure 5-1. Observed water temperatures in the South Yuba River below Poorman Creek are shown in Figure 5-2.

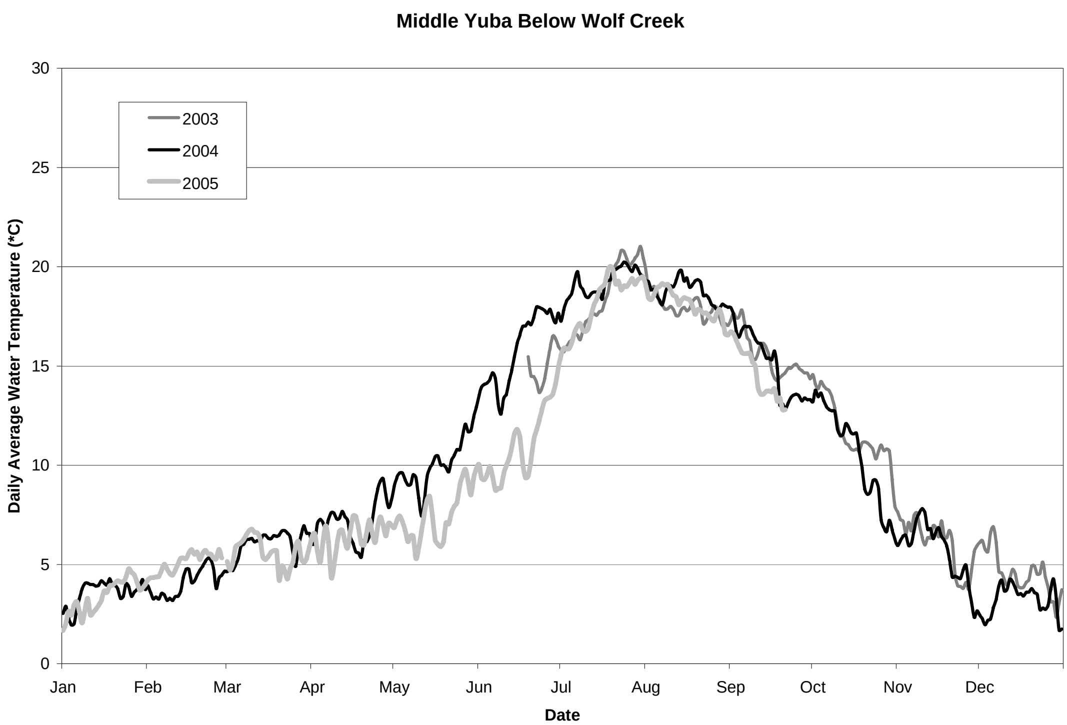

FIGURE 5-1
Observed Water Temperatures in the Middle Yuba River Below Wolf Creek

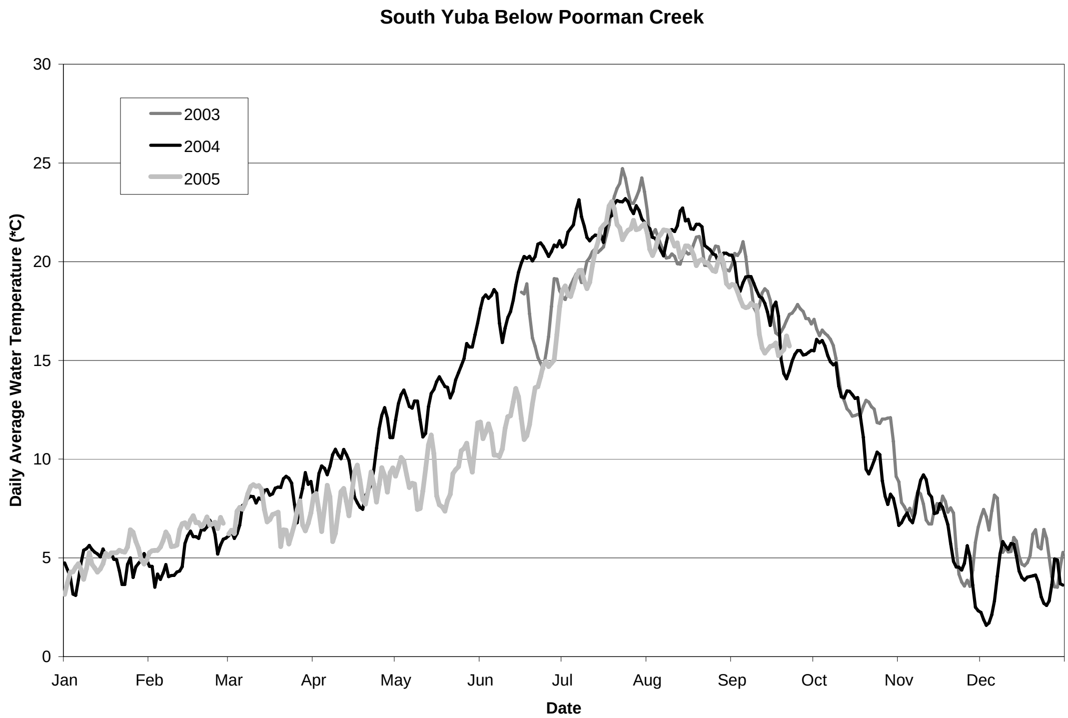

FIGURE 5-2
Observed Water Temperatures in the South Yuba River Below Poorman Creek

The water temperature model was used to investigate the effect of high summer air temperatures and other more extreme meteorological conditions observed in 2003 on water temperatures during a period of more typical summer low flows (2004). The model scenario consisted of using the meteorological data for 2003 and the hydrology observed in 2004 in a model run for comparison to the initial 2004 model run. Water temperatures using this scenario were higher than predicted (or observed) in 2004 at intermediate locations due to the increased heat input represented by the 2003 met data (Figure 5-3).

The analysis of thermally suitable habitat was repeated using the higher predicted water temperatures to examine the effect of more extreme meteorological conditions on the amount of habitat considered suitable for spring-run Chinook salmon and steelhead. Figure 5-4 shows the distribution of thermally suitable habitat in the Middle Yuba River for spring-run Chinook salmon predicted using the 2003 met data. Figure 5-5 shows the distribution of thermally suitable habitat in the Middle Yuba River for steelhead predicted using the 2003 met data. Results of this analysis suggest that in years with particularly high air temperatures and low flows, the amount of thermally suitable habitat and the number of Chinook salmon and steelhead that could successfully spawn in the Middle Yuba River would be reduced.

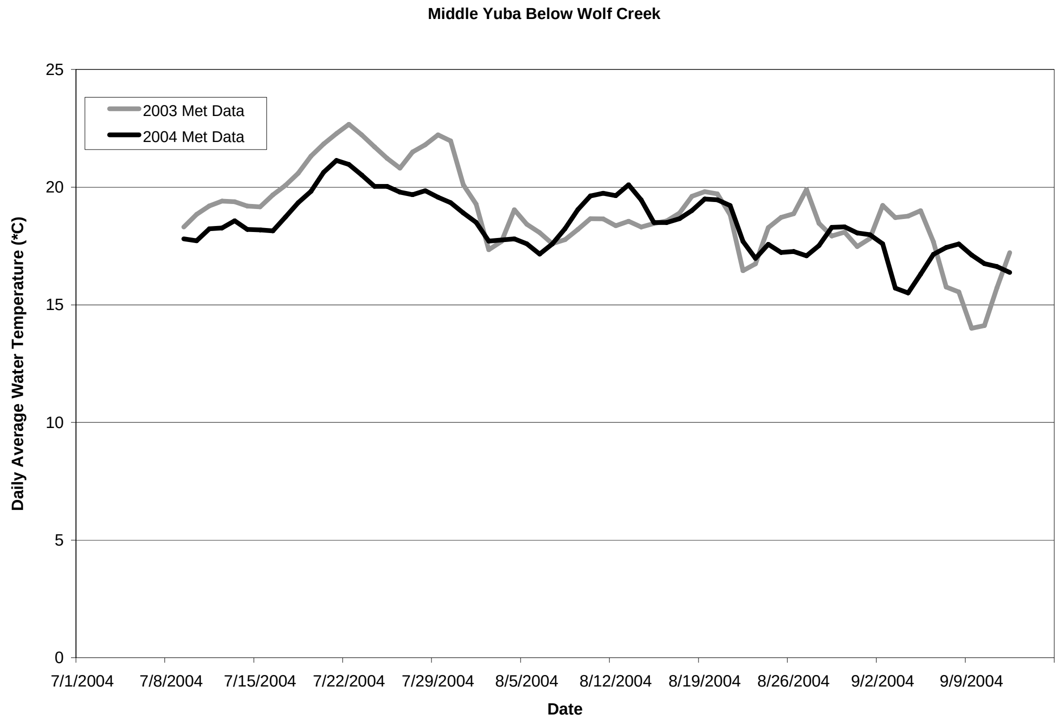

FIGURE 5-3
Comparison of Predicted Water Temperatures in the Middle Yuba River Below Wolf Creek
Using 2003 and 2004 Met Data with 2004 Hydrology

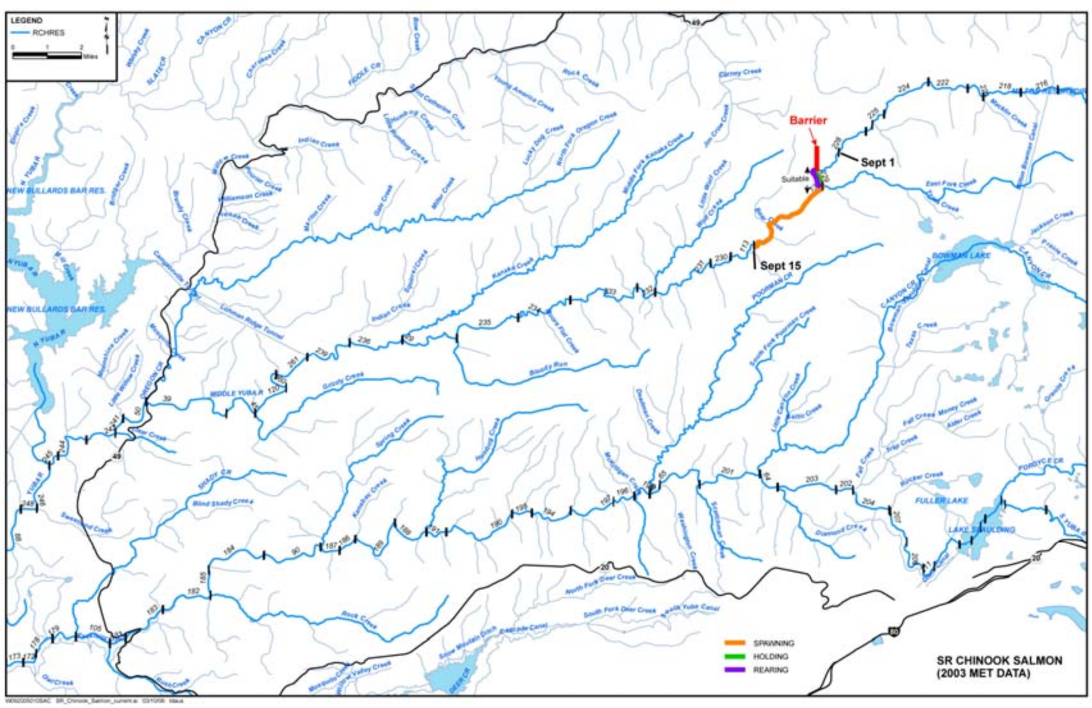

FIGURE 5-4
River Reaches with Suitable Water Temperatures for Spring-run Chinook Salmon
in the Middle Yuba River Predicted Using 2003 Met Data.

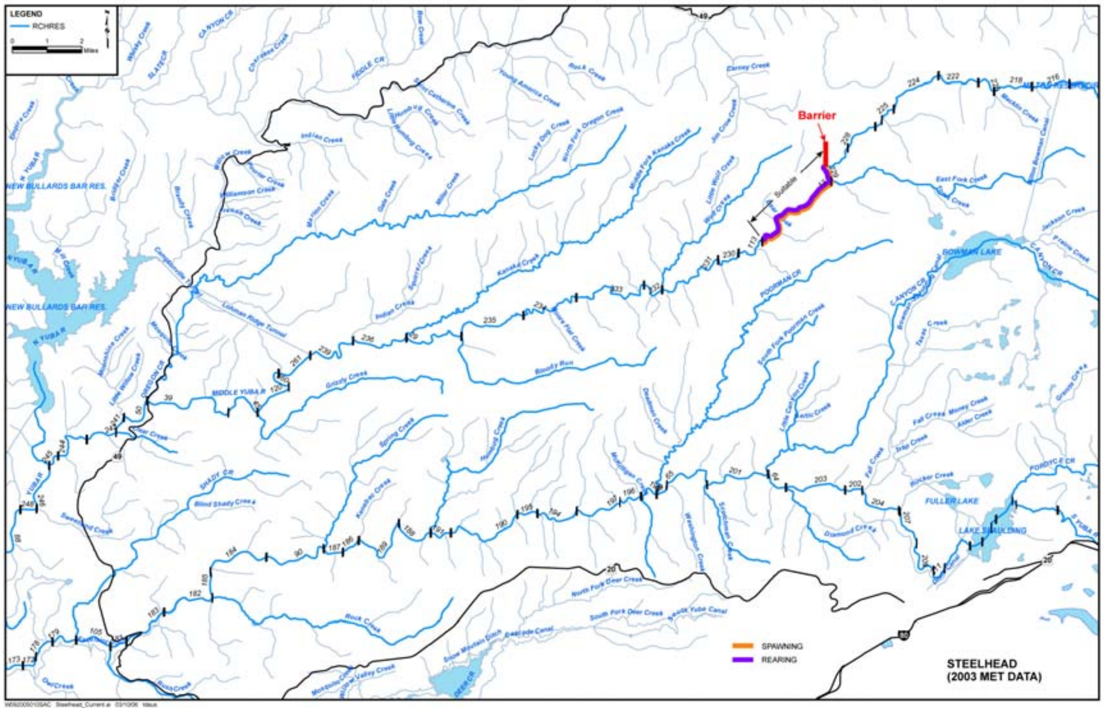

FIGURE 5-5
River Reaches with Suitable Water Temperatures for Steelhead in the Middle Yuba River Predicted Using 2003 Met Data

5.1.2 Boundary Conditions for Increased Flow Scenarios

The water temperature model was used to predict the effect of increased releases from Jackson Meadows Reservoir through Milton Reservoir on water temperatures in the Middle Yuba River, and the effect of increased releases from Lake Spaulding on water temperatures in the South Yuba River. In all cases, it was assumed that release temperatures would remain equal to observed temperatures below Milton Dam and Lake Spaulding and would not change with increased flows. Changes in water temperatures at the release point could alter the downstream extent of thermally suitable habitat and the predicted number of spring-run Chinook salmon and steelhead that could be supported in the available habitat.

Insufficient information was available to confirm the assumption that boundary temperatures would not change with increased flows. However, because releases from Milton Dam into the Middle Yuba River are controlled through releases from Jackson Meadows Reservoir, and releases from Jackson Meadows come from the cooler depths of the reservoir, increasing the releases from Jackson Meadows is unlikely to substantially alter the water temperature that would result below Milton Reservoir in the Middle Yuba River unless the increased release resulted in depletion of the cold-water pool in Jackson Meadows. If this were the case, the release temperature would increase and the length of thermally suitable reaches downstream would decrease.

The same uncertainty about the use of observed water temperatures in the increased flow scenarios exists for the South Yuba River. However, very little thermally suitable habitat for spring-run Chinook salmon and steelhead was predicted under the increased flow scenario with 50 cfs and none under current operations. Any additional thermally suitable habitat in the South Yuba River resulting from altered boundary conditions would increase the total number of Chinook salmon and steelhead potentially supported.

5.1.3 Water Temperatures in the South Yuba River

Monitoring data from Langs Crossing and water temperature profile data in Lake Spaulding (Appendix F) indicate a difference of almost 5.5°C between observed water temperatures at Langs Crossing and the water temperature in Lake Spaulding at the low level outlet. The monitoring location (Langs Crossing) is about a mile downstream of the actual release point at Lake Spaulding Dam. While the stream bed between Lake Spaulding and Langs Crossing is largely exposed bedrock, which could contribute to warming of water flowing through this reach, the observed increase is larger than expected based on the short distance between the release and monitoring locations. The increase may partially result from the presence of very large pools in this reach that reduce water movement and increase the amount of time that the stream is exposed to solar radiation (Geary, 2006).

The difference in observed temperatures at Langs Crossing and expected release temperatures from Lake Spaulding also could be attributed to operations at the dam. As indicated in Appendix F (Appendix Figure 8), there is more than one elevation where water can be drawn from Lake Spaulding for release to the South Yuba River. Prior to September 2004, releases from the lake were drawn from the upper and lower intakes resulting in a mixture of water of differing temperatures being released to the South Yuba River (Geary, 2006). This mixture was likely of a higher water temperature than observed at the lowest elevation (greatest depth) in the Lake Spaulding temperature profiles. After September 2004, releases to the South Yuba River were made from the low level outlet, and may have resulted in cooler releases to the river. However, sporadic water temperature measurements at Langs Crossing in July and August of 2005 were no cooler than temperatures observed in 2004 and earlier years (Geary, 2006).

This change in release elevation (and potentially release temperature) could affect the habitat analysis through alteration of anticipated water temperatures under current (2004) operations and with increased flows. Unfortunately, the data logger at the Langs Crossing monitoring location was lost sometime after September 2004 and there are no monitoring data from this location in 2005 with the change in operation. This makes it impossible to analyze the potential change in the amount of thermally suitable habitat resulting from the operational change in release elevation. However, comparison of water temperatures in 2003, 2004, and 2005 downstream at Poorman Creek (approximately 13 miles downstream) indicate that summer water temperatures in 2005 were not appreciably different from prior years (see Figure 5-2). Above Canyon Creek (RM 33), approximately 2.5 miles below the barrier to migration, observed summer water temperatures were similar in 2003 and 2005 (see Appendix F). This suggests that if there was a change in boundary conditions resulting from the change in release point to the low level outlet, it had little effect on downstream water temperatures in the South Yuba River.

The minimal response in downstream water temperatures to a possible change in release temperatures from Lake Spaulding suggests that the use of observed water temperatures below Spaulding Dam as the boundary condition for the increased flow scenarios in the South Yuba River was appropriate for the feasibility level analysis. The study team does acknowledge that changes in the boundary conditions could affect water temperatures in the South Yuba River between Langs Crossing (RM 41) and Poorman Creek (RM 28); thus affecting the extent of thermally suitable habitat for spring-run Chinook salmon and steelhead in this reach. Approximately half of this reach is inaccessible to these species due to the barrier at RM 35.4, limiting the effect of altered release temperatures on the amount of thermally suitable habitat. Additional monitoring of water temperatures at the release point, Langs Crossing, and downstream would facilitate a better understanding of changes in operation (and release temperatures) on the extent of thermally suitable habitat for Chinook salmon and steelhead in the upper reaches of the South Yuba River.

5.1.4 Range of Suitable Water Temperatures

Based on a review of available information (Appendix B), water temperature criteria (thresholds) were developed for each life stage of Chinook salmon and steelhead in the Upper Yuba River basin (see Table 2-1). Three thermal zones were defined, corresponding to expected physiological responses of each species and life stage: optimal, suboptimal, and chronic to acute stress. The water temperatures identified as the upper limits of the "optimal" range were intended to be used as threshold values that will avoid lethal and sublethal temperature effects. The upper limits of the "suboptimal" range were used to define thermal suitability for each life stage.

Since the extent of suitable habitat was determined using the relationship between stream temperatures (MWAT) and the threshold values for the upper end of the suboptimal range, it was desirable to understand the sensitivity of the analysis to the chosen criteria. To examine the sensitivity of the habitat analysis to the choice of criteria, the analysis was repeated for the adult holding life stage of spring-run Chinook salmon with temperature criteria of 16°C and 20°C. The lower criteria represents the upper limit of the "optimal" range and the higher criteria of 20°C represents the water temperatures commonly experienced by holding adult spring-run Chinook salmon in Butte Creek (CDFG Unpub. data). Neither of these criteria are intended to describe the precise thermal tolerance of spring-run Chinook salmon or to indicate regulatory criteria that would be applied if salmon and steelhead were introduced into the upper Yuba River watershed. Rather, they are used to illustrate the sensitivity of the habitat analysis to a range of criteria for suitability.

Use of the higher temperature criteria (20°C) would extend the range of thermally-suitable habitat predicted in the Middle Yuba River under current operations to approximately RM 25.6 (below Wolf Creek). Use of the more restrictive criteria based on optimal water temperatures (16°C) would limit thermally suitable habitat in the Middle Yuba River to reaches upstream of approximately RM 33.9 under current operations. Neither of these criteria would alter the conclusion that thermally-suitable habitat on the South Yuba River is limited to the area above the total barrier at RM 35.4. Based on the analysis of spawning habitat (Appendix D), approximately 50 and 480 spring-run Chinook salmon redds could be supported by the available spawning habitat in the thermally-suitable reaches of the Middle Yuba River defined using 16°C and 20°C, respectively under current water operations. Assuming one female Chinook salmon per redd and a sex ratio of 1:1, approximately 100 to 950 adult spring-run Chinook salmon could spawn in the thermally suitable reaches of the Middle Yuba River defined using these criteria. As described above, these estimates are likely conservative for a number of reasons.

The analysis of thermally suitable habitat using the 2003 meteorological data and the 2004 hydrology was repeated using the higher and lower holding criteria to examine the effect of more extreme meteorological conditions on the amount of habitat considered suitable for spring-run Chinook salmon and steelhead with the alternative criteria. The downstream extent of thermally suitable habitat in the Middle Yuba River using the 2003 met data and the higher temperature criteria (20°C) was predicted to occur at approximately RM 30.7 (over 4 miles upstream Wolf Creek). Approximately 150 spring-run Chinook salmon redds could be supported in this reach. Use of the more restrictive criteria based on optimal water temperatures (16°C) would limit thermally suitable habitat in the Middle Yuba River to reaches upstream of approximately RM 40, above the total barrier to upstream migration. Results of this analysis suggest that in years with particularly high air temperatures and low flows, the amount of thermally suitable habitat in the Middle Yuba River would be reduced, potentially to zero.

5.2 Flows Required to Overcome Passage Barriers

The number of barriers identified represents the minimum number because the study team was not able to access all of the sites and, in some instances, was not able to see a barrier adequately in the aerial video because of line-of-site limitations (e.g., shadows, canyon walls), air speed, or videotape clarity. Barriers were identified either low flow or total (high and low flow) barriers based on the predicted interaction of the channel geometry and stream flow (barrier hydraulic conditions), combined with the known leaping abilities of salmon and steelhead. Of particular importance in this assessment were factors such as estimated height of the barriers, plunge pool characteristics, and physical configuration of the barriers (e.g., single or multiple falls, complexity of the falls, chutes, or cascades, fish passage routes, etc.). Not all of these variables could be accurately assessed from the aerial video, and flows at the time of migration could differ from flows at the time of the field surveys. However, based on field examination of several of the low-flow barriers, it was estimated that flows of 100 to 200 cfs would likely provide passage at these barriers. Further detailed, site-specific data and analyses (e.g., channel geometry surveys and hydraulic measurements) would be needed to accurately determine flows required to provide successful fish passage. Physical alteration of the low-flow barriers to accommodate fish passage may be a more feasible than flow augmentation.

5.3 Rearing Habitat

The success of any introduction into the upper Yuba River watershed would depend, in large part, on the ability of juvenile salmonids to successfully rear and emigrate from the system. The number of juvenile salmon or steelhead produced from a basin, and ultimately the number of smolts reaching the ocean, is a direct indicator of the ability of the population to sustain itself. Survival of a given life stage, including downstream migration, ocean residence, and upstream migration, varies considerably and is dependent on a number of factors that are not easily quantified.

5.3.1 Spring-run Chinook Salmon

It is unknown whether juvenile spring-run Chinook salmon would adopt a stream-type rearing strategy and rear in the river for several months before emigrating, or adopt an ocean-type strategy and outmigrate as fry, spending only a few days to a few weeks in the river. Based on observations in Butte Creek (Ward et al., 2004a, b), spring-run Chinook salmon introduced into the Upper Yuba River watershed may emigrate as fry and not rear over the summer due to the relatively high summer stream temperatures.

5.3.2 Steelhead

Steelhead, on the other hand, would be expected to spend at least one summer and winter in the river before migrating downstream to the Delta and ocean. Reaches with suitable water temperatures were defined based on literature values for the range of temperatures anticipated to be chronically or acutely stressful to rearing juvenile steelhead. However, rainbow trout occupy reaches of both the Middle and South Yuba rivers outside of the identified thermally suitable reaches. It is unclear whether the observed individuals (see Appendix G) represent trout that were resident at those locations or were merely present at the locations due to displacement from upstream areas, migration, or chance at the time of the surveys. Despite the observations of rainbow trout, it is possible that conditions at the locations where rainbow trout were observed outside of the identified thermally suitable reaches would be unsuitable to support juvenile steelhead. Insufficient information exists to conclusively determine whether juvenile steelhead could rear outside of the areas identified as thermally suitable. However, if juvenile steelhead were able to rear in reaches downstream of the identified thermally suitable reaches, juvenile steelhead rearing in these additional reaches could contribute an additional increment to the production of steelhead in the watershed.

5.4 Populations Supported in Other Central Valley Streams

To establish the context for the predicted number of spring-run Chinook salmon and steelhead that could spawn in the thermally suitable habitat available in the upper Yuba River watershed, the predicted number of spring-run Chinook salmon that could potentially spawn in the upper Yuba River watershed was compared to other streams supporting these species in the Central Valley of California. Since steelhead migrate and spawn during time periods that make enumeration difficult in most streams, few data are available on steelhead population numbers in the Central Valley and elsewhere. Therefore, no comparison of steelhead numbers was possible. Therefore, only the predicted number of spring-run Chinook salmon in the upper Yuba River watershed was compared to other streams.

Central Valley streams thought to support self-sustaining populations of spring-run Chinook salmon include Deer, Mill, and Butte creeks. Spring-run Chinook salmon are occasionally observed in other streams such as Antelope and Big Chico creeks, but these populations are smaller, intermittent, and are not considered viable populations by the National Oceanic and Atmospheric Administration (NOAA Fisheries). Figures 5-6, 5-7, and 5-8 provide a comparison of the predicted number of adult spring-run Chinook salmon that could spawn in the upper Yuba River watershed (i.e., the Middle Yuba River) with historical estimates of the number of spawners in Deer, Mill, and Butte creeks.

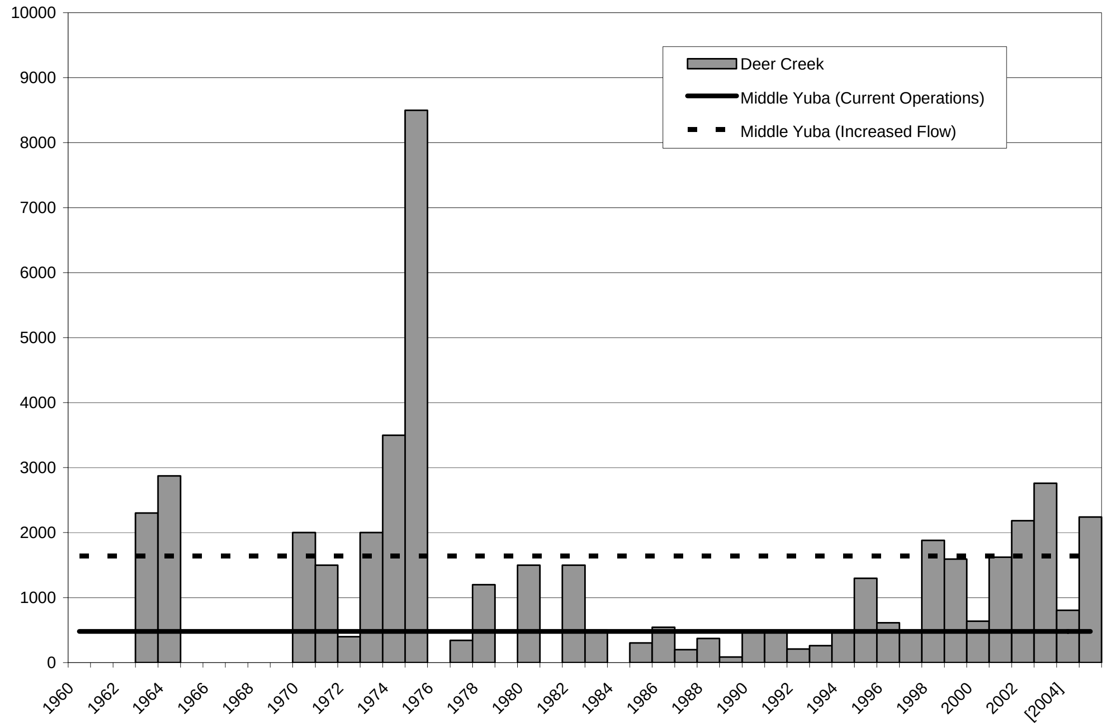

FIGURE 5-6
Historical Run Size of Spring-run Chinook Salmon in Deer Creek Compared to the Potential Number of Spawners in the Middle Yuba River
Data from CDFG

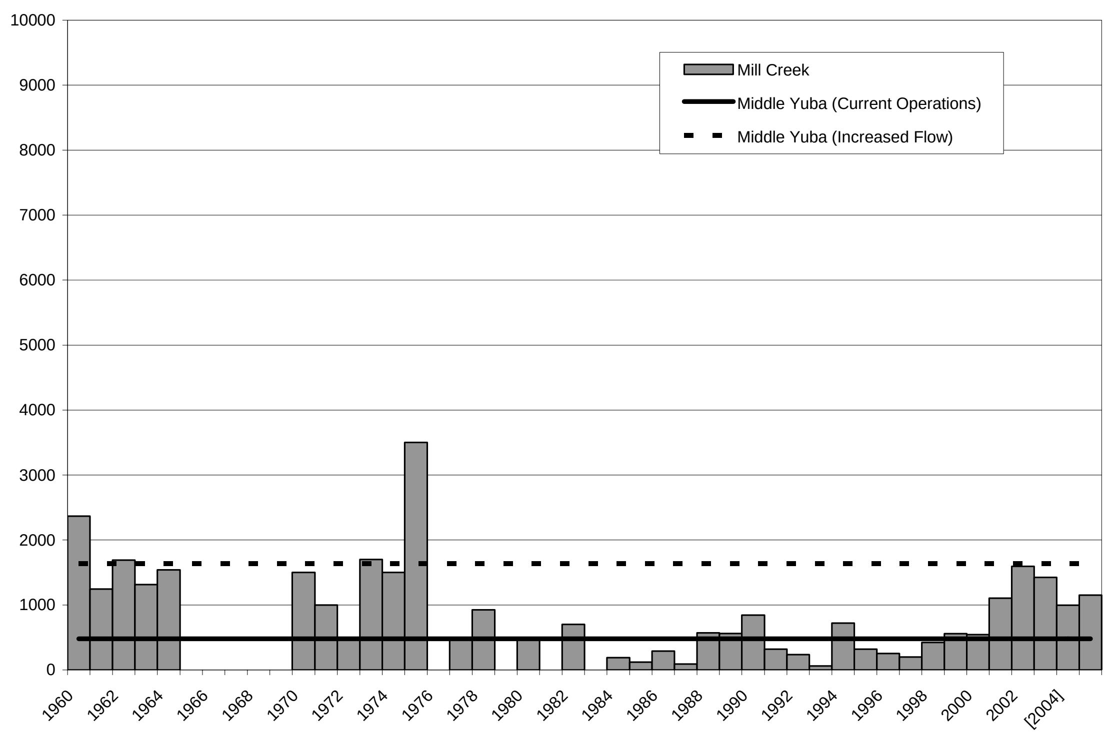

FIGURE 5-7
Historical Run Size of Spring-run Chinook Salmon in Mill Creek Compared to the Potential Number of Spawners in the Middle Yuba River
Data from CDFG

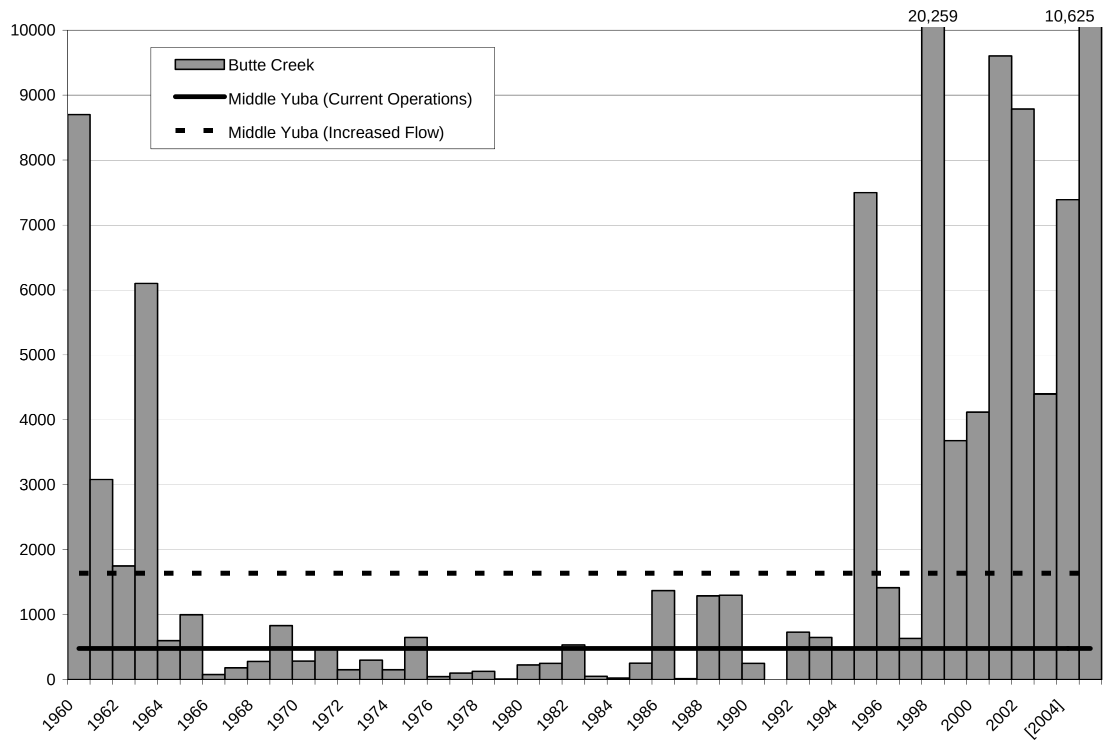

FIGURE 5-8
Historical Run Size of Spring-run Chinook Salmon in Butte Creek Compared to the Potential Number of Spawners in the Middle Yuba River
Data from CDFG

The potential number of spawners in the Middle Yuba River under current operations is comparable to or greater than the historical run size in many years in the comparison streams. Under conditions of increased flow (50 cfs), the potential number of spawners in the Middle Yuba River is greater than the historical run size in many years in the comparison streams. Although numerous factors affect population sizes in these streams, comparison of historical run sizes with the predicted number of adults in the upper Yuba River watershed provides some guidance regarding the potential for the upper Yuba River watershed to support sustainable populations.

The reasons for the difference in spring-run Chinook escapement in Butte Creek compared to Mill and Deer creeks are not well understood. Both Mill and Deer creek possess relatively pristine habitats for spring-run Chinook salmon in the upper reaches of each watershed. Also, those watersheds exhibit a relatively natural runoff pattern. Alterations to Mill and Deer creeks have primarily occurred in the lower-most reaches on the valley floor due to agricultural practices (e.g., water diversions and cattle grazing). However, the majority of possible impacts to fish in these two creeks have been ameliorated in recent years (e.g., improved fish passage at dams and screened water diversions). In contrast, salmon in Butte Creek spawn at lower elevations than in Mill and Deer creeks, and the watershed and runoff patterns are highly altered. In Butte Creek, water operations in the lower reaches are complex, although recently, measures have been implemented to reduce impacts of agricultural water operations on salmon. Also, winter-time flows in lower Butte Creek are often distributed over large floodplains and flood bypasses on the valley floor prior to entering the Sacramento River. It is possible that the recent large spring-run Chinook salmon runs in Butte Creek can be, at least partially, attributed to improved survival during outmigration due to juvenile rearing on floodplains. Recent studies of juvenile salmon rearing in flood plains elsewhere in the Central Valley suggest that fish survival and growth may be enhanced in those areas (Sommer et al., 2001a, b).

CHAPTER 6

Conclusion

As described in the previous chapters, results of the field studies on physical habitat elements were integrated with what is known about water temperatures in the upper Yuba River watershed and the temperature tolerances of Chinook salmon and steelhead to evaluate the ability of available habitat in the Middle and South Yuba rivers to support these species. There is inherent uncertainty associated with this analysis, especially given that the habitat evaluated is not currently occupied by these species. Therefore, this analysis attempts to provide a logical and objective basis for using the available information to draw preliminary conclusions regarding the availability of suitable habitat for Chinook salmon and steelhead upstream of Englebright Dam and the capability of this habitat to support these species. The analysis required the use of informed assumptions to arrive at the preliminary predictions. Where possible, conservative assumptions were used in the analyses to ensure that:

- The amount of suitable habitat and the number of fish it could support was not overestimated
- The abilities of salmonids to repopulate new habitat areas through straying, acclimation, and behavioral adaptation was given full consideration
- Results of the analyses would be robust enough to be applicable under a range of conditions, given the level of variability inherent in biological systems
- Uncertainty in the analyses would not materially alter the conclusion regarding potential use of the upper Yuba River watershed by Chinook salmon and steelhead

The results of the habitat analyses, based on temperature and hydrologic conditions in 2004 and a number of conservative assumptions, suggest that a small number of spring-run Chinook salmon (100 to 950 adults) could spawn in the available habitat on the Middle Yuba River under current operations. The predicted number of spawners in the Middle Yuba River is comparable to or greater than the historical run size in many years in other Central Valley streams. Results also suggest that a similar number of steelhead (approximately 650 adults) could spawn in the available habitat on the Middle Yuba River under current operations. However, the analysis suggests that the South Yuba River could not support spring-run Chinook salmon or steelhead under current operations due to high summer water temperatures.

Additional flow released from Milton Reservoir at the top of the Middle Yuba River would increase the linear extent of reaches with suitable water temperatures for spring-run Chinook salmon and steelhead. This increased area could potentially support a higher number of spring-run Chinook salmon and steelhead adults than under current operations. Increased flows in the South Yuba River could alter thermal conditions such that a small number of Chinook salmon and steelhead could potentially be supported in the very upper reaches of the river. Additional flow could also aid in providing passage at the low-flow barriers, increase the amount of rearing habitat, and increase the likelihood that introductions would be successful. The availability of cold water in the upstream reservoirs was not addressed in this analysis.

Whether the amount of available thermally suitable habitat under current operations or with increased flows could support self sustaining populations of spring-run Chinook salmon or steelhead over the long term is dependent on a number of factors that were not examined during the field studies conducted for the UYRSP including:

- Annual variability in meteorological and hydrologic conditions that could affect the amount of thermally suitable habitat available
- The genetic structure of potential broodstock from the lower Yuba River and elsewhere
- Potential losses of juvenile salmonids at existing water diversions
- Pre-spawn mortality of adults migrating upstream to thermally suitable reaches
- Potential mortality of juvenile salmonids due to predation in the rivers and Englebright Lake
- Potential passage-related mortality of adult and juvenile salmonids

These and other factors could be examined in future studies to refine the predicted number of salmon and steelhead that could be supported in the available habitat and help determine the likelihood that populations would be self sustaining over the long term.

The results of this analysis represent the initial steps in determining overall feasibility and provide the technical basis for determining whether moving forward with the next steps in the overall evaluation is justified. These results alone do not constitute a conclusion that introduction of Chinook salmon or steelhead would be biologically feasible over the long term. Completion of the additional studies identified in the UYRSP study plan, and additional evaluation of biological and habitat issues would be required to ultimately determine the feasibility of introducing Chinook salmon and steelhead into the upper Yuba River watershed.

Additional analyses that could help to resolve several of the biological and habitat issues that affect the feasibility of introduction could include:

- Site surveys of the low-flow barriers to determine the flows required to provide upstream passage for adult Chinook salmon and steelhead
- Continued water temperature monitoring to evaluate annual variability and how changing operations may affect water temperatures and the amount of thermally suitable habitat
- Evaluation of cold water availability in the upper reservoirs and assessment of flow availability using the water supply model
- Characterization of the reach between Lake Spaulding and Langs Crossing to better define the boundary conditions and effects of increased releases into the South Yuba River
- Population-level modeling to help determine if the predicted number of adults represents a population that would be self-sustaining over the long term

CHAPTER 7

References

California Department of Water Resources (DWR). 2003. Interim Report, Summary of Current Conditions ion the Yuba River Watershed. Prepared by the Upper Yuba River Studies Program Study Team.

Everest, F.H., and D.W. Chapman. 1972. "Habitat Selection and Spatial Interaction by Juvenile Chinook Salmon and Steelhead Trout in Two Idaho Streams." *Journal of the Fisheries Research Board of Canada*. 29: 91-100.

Geary, Gene. (PG&E). 2006. Personal communication. Conversations via phone and e-mail with Neil Nikirk (CH2M HILL) on March 28-29, 2006.

McCuddin, M.E. 1977. Survival of Salmon and Trout Embryos and Fry in Gravel-Sand Mixtures. Master's thesis. University of Idaho, Moscow.

McEwan, D., and T.A. Jackson. 1996. *Steelhead Restoration and Management Plan for California*. California Department of Fish and Game, Inland Fisheries Division, Sacramento, Management Report.

Moyle, P.B. 2002. *Inland Fishes of California*. Revised edition. University of California Press, Berkeley.

Nicholas, J.W., and D.G. Hankin. 1989. *Chinook Salmon Populations in Oregon Coastal River Basins: Descriptions of Life Histories and Assessment of Recent Trends in Run Strengths*. Report EM 8402. Oregon Department of Fish and Wildlife, Research and Development Section, Corvallis.

Sommer, T.R., M.L. Nobriga, W.C. Harrell, W. Batham, and W.J. Kimmerer. 2001a. "Floodplain Rearing of Juvenile Chinook Salmon: Evidence of Enhanced Growth and Survival." *Canadian Journal of Fisheries and Aquatic Sciences*. 58: 325-333.

Sommer, T., B. Harrell, M. Nobriga, R. Brown, P. Moyle, W. Kimmerer, and L. Schemel. 2001b. "California's Yolo Bypass: Evidence that Flood Control Can Be Compatible With Fisheries, Wetlands, Wildlife, and Agriculture." *Fisheries* 26: 6-16.

Stillwater Sciences. 2006. *Upper Penitencia Creek Limiting Factors Analysis*. Final technical report. Prepared by Stillwater Sciences, Berkeley, California for Santa Clara Valley Urban Runoff Pollution Prevention Program, Oakland, California.

Tagart, J.V. 1976. The Survival from Egg Deposition to Emergence of Coho Salmon in the Clearwater River, Jefferson County, Washington. Master's thesis. University of Washington, Seattle.

Ward, P.D., and T.R. McReynolds. 2001. *Butte and Big Chico Creeks Spring-run Chinook Salmon,* Oncorhynchus tshawytscha, *Life History Investigation 1998-2000*. CDFG Inland Fisheries Administrative Report No. 2001-2. 61 pp.

Ward, P.D., T. R. McReynolds and C. E.Garman. 2004a. *Butte Creek and Big Chico Creeks Spring-run Chinook Salmon,* Oncorhynchus tshawytscha*, Life History Investigation, 2000-2001*. Calif. Dept. of Fish and Game, Inland Fisheries Admin. Report No. 2004-3. 47 pp.

Ward, P.D., T.R. McReynolds and C.E. Garman. 2004b. *Butte Creek and Big Chico Creeks Spring-run Chinook Salmon,* Oncorhynchus tshawytscha*, Life History Investigation, 2002-2003*. Calif. Dept. of Fish and Game, Inland Fisheries Admin. Report No. 2004-6. 43 pp.